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Turning the Tide: Digitalization and Resilience in Swedish Small and Medium-Sized Ports

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Abstract

This study investigates how digitalization, particularly through the implementation of Intelligent Transport System (ITS), contributes to operational resilience and efficiency in Swedish small and medium-sized ports (SMSPs). Including a particular focus on the Port of Södertälje. In the context of increasing supply chain disruptions and pressure from regulatory frameworks such as the European Unions (EU) Trans-European Transport (TEN-T) network, SMSPs faces challenges stemming from limited resources, outdated infrastructure and low digital maturity. Using a mixed-methods approach including semi-structured interviews and a stakeholder survey, the study explores how digital tools can improve information flow, stakeholder collaboration and adaptive capacity. The findings reveal a fragmented landscape where manual coordination remains dominant. However, evidence shows that terminal operating systems, real-time data platforms, and predictive analytics have significant potential in improving disruption management and long-term adaptability. The study identifies a mismatch between public-sector digital initiatives and private-sector needs, highlighting a need for shared platforms, standardized systems and stronger inter-organizational integration. This research contributes to the understanding of digitalization's role in port resilience and provides strategic recommendations for bridging the digital divide in SMSPs.

Key Words: Digitalization, port resilience, Intelligent Transport Systems (ITS), small and medium-sized ports, Port of Södertälje, information flow, supply chain disruptions

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List of Abbreviations and Definitions

ITS - *Intelligent Transport Systems* – Digital systems designed to improve the efficiency, safety, and sustainability of transport operations through real-time data, automation, and integrated infrastructure.

SMSPs - *Small and Medium-Sized Ports* – Ports with limited infrastructure, capacity, and digital maturity compared to large or core ports, often playing vital roles in regional supply chains.

TEN-T - *Trans-European Transport Network* – A European Union policy initiative aiming to build an integrated and efficient transportation network across EU member states.

ICT - *Information and Communication Technology* – Technologies used for communication and the processing and dissemination of information, critical in digital port operations.

TOS - *Terminal Operating System* – Software solutions used to manage the movement and storage of cargo in ports, streamlining operational processes.

Digitalization - The use of digital technologies to change a business model, improve operations, and deliver new value-producing capabilities.

Port Resilience - The ability of a port to withstand, adapt to, and recover from disruptions such as extreme weather, cyberattacks, or logistical bottlenecks.

Disruption - Any event or condition that interrupts normal port operations or supply chain flows, including natural, technical, human, or economic causes.

Information Flow - The process by which data and information are transmitted between stakeholders in the supply chain, crucial for coordination and decision-making.

1. Introduction

In this chapter, the context and motivation for the study are explained. It outlines the background, identifies the research problem, and presents the research questions and objectives that guide the study.

1.1 Background

Ports are essential nodes in regional and global supply chains through facilitating trade and the efficient movement of goods. Simultaneously, the port contributes to employment, trade and industrial development supporting sectors ranging from manufacturing to energy (Gerlitz & Meyer, 2021). In Sweden, approximately 90 percent of exports and imports depend on maritime transport (Lind, et al., 2021). Therefore, their efficiency directly affects supply chains, impacting lead times, logistics costs, and trade flows. However, ports are highly vulnerable to disruptions ranging from natural disasters and infrastructure failures to geopolitical conflicts and supply chain bottlenecks (Notteboom et al., 2022). Since global logistics has become increasingly complex even minor disruptions in port operations can cause rippling effects throughout their supply chains. Leading to economic losses and inefficiencies (Tang & Tomlin, 2008a). To be resilient; the ability to absorb, adapt to, and recover from such disruptions, is therefore an important priority for port operations (Chowdhury & Quaddus, 2016).

An enabler for port resilience can be digitalization. The adoption of Intelligent Transport Systems (ITS), automation, and real-time data analytics enhances a ports ability to anticipate, monitor and respond to disruptions effectively (Notteboom et al., 2022). Digital technologies improve situational awareness, decision-making and crisis responses and supports ports in maintain operational continuity during disruptions (Fan & Stevenson, 2018). Technologies such as predictive analytics, remote monitoring, and automated systems allow for early detection of risks such as port congestions, weather related delays, or supply chain breakdown (Lind et al., 2021). While there exist relatively high digital maturity in large ports, many small and medium sized ports (SMSPs) struggle to implement comprehensive digital strategies due to financial constraints, outdated infrastructure and limited IT expertise (Almeida, 2023). For the purposes of this study, SMSPs are defined as ports handling up to 50 million tonnes of cargo annually or up to 2 million twenty-foot equivalent units (TEUs). This aligns with the threshold suggested by Verhoeven (2010) and the World Bank (2022). This definition reflects both bulk and container throughput criteria relevant to Swedish port contexts.

The Port of Södertälje provides an interesting case to examine the link between digitalization and resilience in SMSPs. Located 35 km southwest of Stockholm, it is one of Sweden's key

inlands ports connected to the Baltic Sea via Södertälje Canal. The location acts as premisefor the port to act as a crucial logistics hub for the Stockholm-Mälaren region, the largest consumer region in Sweden's ('Handeln i Sverige', n.d.). The port offers multimodal transport through an integration of maritime, road and rail networks. Further, it is in close proximity to major Swedish industrial actors such as Scania and AstraZeneca, and the evolving logistic hub Stockholm Syd.1 Despite its strategic significance, according to a project coordinator at Swedish consultancy firm, the Port of Södertälje faces infrastructure limitations, increasing freight demand, and a need for digital modernization (personal communication, March 5, 2025). Unlike larger port which have extensive digital maturity, many Swedish SMSPs including Södertälje, lack fully integrated digital solutions (Lind, et al., 2021). This can make them vulnerable to disruptions such as supply chain shocks, climate-related risks, and logistical efficiencies. While initiatives aim to improve sustainability and intermodals transport, digitalization remain an underexplored initiative in enhancing resilience and long-term competitiveness.

1.2 Problem Discussion

Having recognized that digital technologies can enhance ports' resilience, there exists a lack of research for how SMSPs will achieve this transition. Since its unique location and offering of transport services, the Port of Södertälje is positioned to function as a key logistics node both regionally and nationally. However, like many SMSPs it faces systematic challenges in achieving digital maturity (Lind, et al., 2021) While larger ports such as Rotterdam and Hamburg have made significant advancements in adopting digital technologies, SMSPs often have limited resources and a lack of technical expertise to enable this transition (Gerlitz & Meyer, 2021). This lack of digitalization increases vulnerability to disruptions, such as supply chain bottlenecks, infrastructure breakdowns, or other operational efficiencies.

One of the key challenges for SMSPs is their limited financial and human resources. SMSPs often struggle to secure the capital needed to implement digital systems. This limitation is worsened by dependence on older and often fragmented infrastructure, which is not compatible with modern digital technologies. Without a certain level of digitalization ports can face difficulties in responding efficiently to unexpected events such as vessel delays, labour shortages or fluctuations in freight volumes. Additionally, there often exist a division in the operations of SMSPs which hinder progress. Meaning, that the collaboration and data sharing between stakeholders such as port authorities, shipping companies and inland transport operators are often limited or inadequate. This results in crisis response and limit's ability to

[1] Stockholm Syd is a logistics and intermodal terminal located between Södertälje and Nykvarn.

recover quickly from disturbances. Further, the lack of integration limits operational efficiency and diminish the potential benefits from digitalization (Gerlitz & Meyer, 2021; M Karlsson et al., 2024; Lind et al., 2021).

Another key challenge is the disconnect between smaller ports and their broader supply chain partners. This *disconnect* refers to the lack of alignment, communication and integration in both operational technological terms. Specifically, the ports struggle to effectively exchange data, coordinate logistics processes or meet the digital expectation of larger actors in the supply chain. Therefore, SMSPs often face disadvantages due to their institutional proximity and influence to collaborate with larger ports and global supply chain actors. Therefore, it limits their ability to integrate into broader digital ecosystems which require interoperable systems and shared standards (Gerlitz & Meyer, 2021). When critical disruptions occur, small ports can struggle to adapt to changing logistics since there is a lack of integration with broader supply chain systems or wider logistics networks. At the same time, the increasing pressure from the European Union to comply with sustainability and digital transformation goals compound these challenges. The revised TEN-T regulation requires ports to meet certain digital and environmental standards by 2030, including interoperability for multimodal logistics, deployment of digital systems and resilience planning measures (*Trans-European Transport Network (TEN-T) - European Commission*, n.d.-a)

These challenges, namely, limited financial and human resources, low levels of digital maturity, and fragmented stakeholder coordination, are relevant in the case of the Port of Södertälje. The port must address resource limitations, establish a digitalization strategy and foster collaboration across the supply chain. While there exists, a unique opportunity to be part of the TEN-T network and the subsequent investments it enables, infrastructural, environmental and digital transition must be combined. For instance, the port cannot reduce energy consumption without having specific digital monitoring tools implemented in the required port areas, and vice versa (Gerlitz & Meyer, 2021). To be able to implement tools such as real-time monitoring systems, digital twins or automated logistics platforms, the port needs to achieve a digital transformation. By overcoming these barriers, it can position itself not only as a transportation node, but as a digital node in the logistics network.

1.3 Research Purpose

The purpose of this research is to examine how digitalization initiatives, particularly Intelligent Transport Systems (ITS), are being implemented in Swedish small and medium sized ports (SMSPs) to enhance operational efficiency and resilience. Focusing on The Port of Södertälje, the study aims to assess how digital tools contribute to improving information flow, stakeholder collaboration, and crisis management regarding disruptions. By identifying key challenges and

opportunities, in port digitalization, the research seeks to provide strategic recommendations for implementing ITS solutions that enhance efficiency, service reliability, and long-term resilience against supply chain disruptions.

1.4 Research Questions

RQ1: How are digitalization initiatives (ITS) being implemented in Swedish small and medium-sized ports (SMSPs) to enhance operational efficiency and resilience, particularly during disruptive events?

RQ2: How does digitalization (ITS) improve information flow among port actors, and how does this contribute to strengthening resilience in the Port of Södertälje?

1.5 Delimitations

This study investigates how digitalization initiatives contribute to operational efficiency and resilience in Swedish small and medium-sized ports (SMSPs), with a particular focus on the Port of Södertälje. The first research question is addressed through a broader review on digitalization efforts linked to resilience and disruptions, with a focus on efforts across other Swedish ports. The second research question is explored through an in-depth case study of Södertälje, drawing on stakeholder perspectives. While the study is contextually grounded in Sweden, its aim is to generate insights that are analytically generalizable to similar port sizes. The study does not evaluate technical system performance but focuses on how digitalization is experienced and understood by those engaged in port-related operations. By choosing these delimitations we create a clear focus of what to research.

The study did not include interviews with representative from the Port of Södertälje authority and instead focuses on the private stakeholders. The actors rely on the port's services and infrastructure, and it allowed for a stronger and unique case focusing on the private actors, and how these external actors perceive the ports resilience and digitalization, as well as preparation and response for disruption. This gives the research the ability to compare the key themes from a public i.e., SMSPs ports in Sweden, and private, i.e. port stakeholders to understand the needs of the different sectors of the port industry.

2. Literature Review

This chapter reviews the existing literature on supply chain disruptions, resilience and the role of digitalization in ports and their ecosystems, with a particular focus on small and medium-sized ports (SMSPs). The purpose of this review is to contextualize the study's focus on how digital tools and Intelligent Transport Systems (ITS) can support or hinder operational efficiency and resilience in ports like Södertälje. The chapter explores key concepts such as supply chain vulnerability, digital maturity, resilience, disruptions and port governance. Additionally, the case of the Port of Södertälje is put in context.

2.1 Supply Chain Disruptions

Supply chain disruptions (SCD), refers to a situation where the normal flow of information, goods and services are unexpectedly interrupted by an external event which leads to lower levels of operational efficiency, customer satisfaction as well as financial losses (Tang, 2006; Tang & Tomlin, 2008b). These disruptions can add to exponential effects on the global supply chains leading to longer lead times, higher costs and more delays in deliveries and production. In complex and connected networks, even small disruptions can create large shortages and challenges (Tang, 2006; Tang & Tomlin, 2008b). Different types of unexpected events that lead to this interruption, or rather disruption, originate from different starting points and have varying characteristics, such as geopolitical tensions, natural disasters, supplier shortcomings and fluctuations in demand. Compared to operational risks, key components of SCDs are their sudden and acute impact on the overall performance of the supply chain (Tang, 2006). SCDs emerge from unpredictable and predicable factors alike and can cause both long-term risks strategically and short-term inefficiencies. Tang & Tomlin (2008) explain disruptions as six major categories, including Supply Risks, Process Risks, Demand Risks, Intellectual Property Risks, Behavioral Risks, Political & Social Risk.

Building on this further, Ali et al. (2021) establishes a framework with 4 categories to understand SCDs. This proposed structured model also explains which specific drivers are key in supply chain resilience. The four categories of Supply Chain Disruptions are:

i. *Natural Disruptions*. Which arise from climate and environmental events such as floods & heavy rains, earthquakes, extreme weather and outbreak of diseases and pandemics. These are hard to predict but can be included in risk models.
ii. *Human-Made Disruptions*. These are created by human actions, such as socio-political factors and regulatory changes. This includes political instability, protests and labor strikes, threats to security and terrorist attacks, traffic, and port congestion.

iii. *System Accidents*. These include mishaps and failures in technology or operations, including fires, faulty equipment and machines, utility failures such as power outages, or system crashes, e.g. cyber-attacks.

iv. *Financial Disruptions*. These are caused by financial instability through issues of bankruptcies, change in currency valuation and limited cash flow. The key drivers for this are bank interest rates fluctuating, bankruptcy of businesses and suppliers, and volatile exchange rate (Ali et al., 2021)

These ways to classify SDCs in their respective models by Tang & Tomlin (2008) and Ali et al. (2021) lays out a foundation for a well-structured understanding of disruptions through key categorization and identification of the different drivers that create them. However, disruptions evolve, and so the need for business to do so also continues to exist. This makes a better understanding of resilience approaches and measures necessary to be able to adapt to the challenges created by distribution.

2.2 Resilience

The concept of Supply Chain Resilience (SCR) has become essential in Supply Chain Management (SCM), caused by the increased challenges and vulnerabilities stemming from globalization, lean practices and disruptions, such as natural disasters, cyber security threats and geopolitics (Christopher & Peck, 2004). Robustness focuses on being able to survive shocks, without needing to change, while resilience focuses on being able to adapt to disruptions. Christopher & Peck (2004) define resilience as *"the ability of a system to return to its original state or move to a new, more desirable state after being disturbed"* (p. 2). The key is transformation and recovery, supply chains that are resilient can reach the existing conditions pre disruptions, as well as may be able to adapt to the crisis and become stronger. There are three key dimensions of SCR: readiness, response, and recovery.

i. *Readiness*. Entails preparing for disruptions through scenario planning, risk identification, redundancy, and visibility. Through strong readiness strategies early signs can be detected and mitigation for disruptions properly planned.

ii. *Response*. Entails implementing a relocation of resources, contingency plans, and continuing operations during adverse conditions, and the ability of an organization to do so successfully. Flexibility, agility, and coordination during a crisis caused by disruption are key factors that exhibit a resilient supply chain. Successfully implementing these characteristics limits damage to operational efficiency and customer service levels.

iii. *Recovery*. Entails returning to the original state or transforming into a more resilient system during the post disruption phase. Organizations with a strong recovery strategy enhance long term success and limits financial loss.

These dimensions put a high focus on proactive and reactive measures to mitigate disruptions, while also aligning well with crisis management literature (Chowdhury & Quaddus, 2016). Successfully developing resilience can be determined by a multitude of factors including organizations supply chain orientation, risk management culture, and learning and development.

A supply chain-oriented company creates a management style of trust, collaboration and strategic alignment among managers and partners, leading to improved risk management and capability to respond (Chowdhury & Quaddus, 2016). A company with well develop risk management culture incorporate cross-functional coordination, continuity planning of the business, and scenario-based risk assessment into the company's broader decisions making (Christopher & Peck, 2004). Through learning and development, companies enhance resilience by conducting employee training, post disruption evaluations, and investments into technologies monitoring risk. Continuous learning from past disruptions improves an organizations ability to adapt (Fan & Stevenson, 2018). SCR and supply chain risk management (SCRM) are closely related topics. SCRM incorporates identification, assessment, treatment, and monitoring of risks. Risk management tries to mitigate the known risks through resilience strategies (Fan & Stevenson, 2018). Christopher & Peck (2004) state that it is not possible to eliminate risk, but through effective management of collaboration, visibility, and scenario planning, it can be managed. Fan & Stevenson (2018) highlights that the current literature of SCRM priorities risk mitigation instead of increased resilience, while companies have a need to start investing in proactive resilience integration.

Lack of empirical validation exists in current research for resilience, and Chowdhury & Quaddus (2016) call for increased focus on company and industry specific research. Digital technologies, such as AI, IoT, blockchain, Machine Learning (ML), and data driven systems will play an important role in bridging the gap between research and the practical situation, and as disruptions continue to becoming more common in the global complex supply chains, it remains an competitive advantage (Fan & Stevenson, 2018).

2.3 Digital Transformation and Digital Maturity

Digital transformation (DT) is defined by Kane et al. (2015) as the processes that a company or organizations undergo to increase integration of digital technologies into all parts of their operations. In other words, shifts the way the company manages internal processes, interact

with customers, and create value for them. Compared to digitalization, digital transformation aims to use digital capabilities more efficiently, through new ways of approaching the business model and a broader objective. To have agility to follow and adapt to the ever-evolving market and to innovative digital technologies and solutions is key to achieving DT. Creating a successful DT is a demanding opportunity with challenges.

Digital maturity is the level of which organisations are capable of shaping themselves after the digital business environment (Kane et al., 2018). It showcases how a company or organisation can combine technologies and digital tools with their business, acting not just as standalone devices but incorporated parts of their operations, strategy, and culture. Usage and implementation of digital tools is common; however, many organisations struggle with achieving digital maturity, partly because it requires experimentation, and partly because it requires looking thoroughly at the organizational challenges (Kane et al., 2018). Achieving this, is not just about adopting technology solutions, but a measure of a company or organisations capacity to shape themselves after the digital business environment through agile response to the quickly changing digital landscape (Kane et al., 2015). Different levels of digital maturity showcase clear difference in cultural, operational, and strategic conduct. This key finding is explained by Kane et al. (2015) which states that companies with a low level of digital maturity implement technological and digital solutions on an individual level instead of through and overarching strategy.

On the other side of the spectrum, companies that have a high level of digital maturity create a strong strategy and vision for their digitalisation work. Through smaller experimental projects, and investment into their workforce digital competence, it leads to better use of technical tools and solutions. Companies with lower levels of digital maturity tend to implement digital solutions in isolated initiatives rather than through a comprehensive strategy. Research indicates that only 15% of these companies have a well-defined and structured digital strategy. In contrast, more than 80% of digitally mature companies integrate digital initiatives into their broader business strategy, ensuring alignment with long-term organizational objectives (Kane et al., 2015). This highlights the critical role of strategic vision in driving successful digital transformation. Strategy is a key driver to achieve effective digital implementation and a digital transformation (Kane et al., 2015). As mentioned briefly, achieving digital maturity comes with challenges and barriers. According to the MIT Sloan report (2018), the main barriers are lack of strategic direction, resistance to change from employees, and failure in the organisation's leadership and culture.

To create a clearer understanding of digital maturity within and around ports, one can observe the shipping and logistics industry. Some industries, like banking, media and

telecommunications have adopted digital transformation well, while the shipping and logistics industry has been lacking behind in this transformation. The industry is a traditional one, and the study done by Raza et al. (2023) found that the main barriers for digital transformation in the shipping industry is a lack of existing digital expertise, organisational silos dividing up important data, and use of legacy systems. This together with low standardisation and homogeneity of digital solutions cause loss of data, low data sharing capabilities and fragmented digital platforms (Raza et al., 2023). To increase digital maturity, companies need to have concise implementation strategies. Research emphasizes four key methods:

i. Inserting digital transformation into core business strategy;
ii. Investing in talent and leadership development;
iii. Creating an agile and experimental culture;
iv. Take apart organisational silos.

Encouraging adaptability and learning increases success of digital transformation by a factor of four, and the long-term advantages of achieving digital maturity, such as increased operational efficiency, innovation and strategic strength allows for a more competitive and thriving business in the ever-transforming digital landscape (Kane et al., 2015, Kane et al., 2018, Raza et al., 2023).

2.4 Digitalization

Digitalization has been recognized as a transformative capacity across industries, in how businesses can reshape business processes, operational models and information flow. There exist several different definitions for digitalization as it differs across industries and business landscapes. In the research conducted by (Reis et al 2020), a literature review was conducted in an attempt to define the term. Following, the definition of digitalization was proposed as; "*digitalization is the phenomenon of transforming analogue data into digital language (i.e. digitization), which, in turn, can improve business relationships between customer and companies, bringing added value to the whole economy and society*" (Reis et al., 2020), pp.448). This definition is somewhat broad and encapsulates social, economic and organizational literature on the term.

In ports, digitalization refers to the adoption and integration of digital technologies to enhance operational efficiency, optimize logistics process and improve information flow within the maritime supply chain (Parola et al., 2021). According to Parola et al., (2021), digitalization enables ports to transition from traditional paper-based operations to automated, data driven systems. Through leveraging technologies such as the Internet of Things (IoT), cloud computing, blockchain, and big data analytics, it can facilitate functions such as real-time cargo

tracking, automated data exchange and predictive analytics. Thus, improving turnaround times and streamlining port logistics. Further, by decoupling information flows from physical cargo movements, digitalization enables integration between port authorities, shipping companies, and hinterland transport which foster a better coordination in the supply chain. Traditionally, information management are often siloed, and digitalization enables the transition to be interconnected, real-time data-sharing environments. Additionally, the implementation of smart sensors, and automated gate storage and gate systems reduces downtimes, minimized bottleneck and ensure a more agile port infrastructure (Parola et al., 2021).

2.5 Intelligent Transport Systems

Intelligent transport systems (ITS) are a key component of digitalization. ITS are integrated applications of ICT (Information and communications technology) across transportation networks. According to Giannopoulos et al., (2012), ITS have the potential to creating integration and cooperation across modes of transports and create a seamless transportation system. The term encompasses a wide range of wireless, electronic, and automated systems. These systems are designed to facilitate real-time data exchange between vehicles, infrastructures and users. Some of the technologies that ITS encapsulates are automated traffic control systems, smart sensors, and predictive analytics. In ports, applications of ITS range from automated gated management systems, AI driven scheduling to automated guided vehicles (AGVs).

Information and communication technologies (ICT) are often deployed to manage, monitor and store a significant amount of data. This data stems from automatic identification systems (AIS), maritime traffic and logistic data, to provide paperless services to their customers. At the same time, ICT systems are dependent on sensing and detection devices such as cameras, sensors, radio-frequency identification (RFID) tags, readers, and bar codes. Through getting the correct data from various location in the operations, it can enable the port to for instance, monitor the environment, track cargo and send information (Yau et al., 2020).

2.6 Risk and Resilience in Ports

The following section draws primarily from the IAPH (International association on ports and harbors) “Risk and Resilience – Guidelines for ports” published in early 2023. It consists of key takeaways of risks for ports, port stakeholder management and port resilience. It is quoted as the following: “*A structured process of defining and inventorying risk, managing stakeholders and building a resilient operational model*” (pp.1). In the context of ports, risk is defined as the effect of uncertainty on achieving objectives, often quantified by the likelihood of an event occurring multiplied by its potential impact. Maritime operations are a complex area, and the

risk that exists is often seen as a negative aspect, however, these risks also come with opportunities for transformation and innovation. The main challenge for ports is high impact and low probability events, and compounding effect of many smaller threats, eventually leading to a major disruption. Risks to ports are categorized into 7 main areas, named events are non-exhaustive:

i. *Economic factors.* Competition, economic climate, bankruptcy, and seasonality.
ii. *Environmental factors.* Seismic events, weather, pollution, Hydrological events unexploded ordinance.
iii. *Human factors.* Events, crime, terrorism, human decision making, industry, epidemics.
iv. *Access factors.* Land and marine access, inspections, customs, security.
v. *Network factors.* Disruptions in the supply chain, ports or hinterland.
vi. *Technological factors.* Accidents, system failures, loss of key functions.
vii. *Organizational factors.* Insufficient resources. Ineffective or lack of planning and communication. Conflicts, bureaucracy.

Port resilience includes the ports' ability to predict, absorb, respond, and recover from disruptions while also remaining functional. Port resilience is an important part of operating a port business in today's global and complex market to survive these challenges. To manage stakeholders in port operations, the PESTEL (Political, Economic, Social, Technological, Environmental, Legal) model is a useful tool. The image below showcases the key factors that influences ports. The 6 factors all have their own aspects and incorporate their own areas of what influence the port operation.

Table 2. 1

Political	Economic	Social	Technological	Environmental	Legal
Geo-political factors that affect your port	A high reliance on single commodities	How the port is seen by the surrounding community	How new technologies can assist a port in its functioning	Ports in the front line of natural disasters and the effects of global warming	Legal stability and assurance as a driver for port development
Regional instabilities or instabilities along the supply chain of your fore-	A high reliance on a little number of clients	How the port can embrace the local community in its business and create a win-win	How technologies can interfere with port operations and make them vulnerable	Ports as polluting industries	Ports at the edge of several legal paradigms: national, international, contractual

and hinterland					
	Picking up on emerging or disappearing commodities	How ports are part of a network		Ports as drivers for ecological innovation	

Table 2.1. PESTEL analysis for port risk assessment. IAPH Risk and Resilience Guidelines for Ports. Own elaboration based on International Association of Ports and Harbors, 2023.

The framework consists of an approach to understanding the opportunities and challenges ports see in their dynamic, complex, and global environment. The PESTEL model is the first step in a three-step process to understand the environment the port operates in. The second step is the key internal factors that affect the ports, and it is its values, vision, mission, governance structure, organizational culture, available resources, relationships to stakeholders and its reliance on technology and digitalization. Lastly, there is a need to understand what level of risk it is that needs to be understood. The operational level (port authority as a single organization), the ports economic activity as a platform for logistics (local stakeholders, and their services), and the port as a node which exercises influence on policy makers and is affected by influence of policy makers in the economy and society (International Association of Ports and Harbors, 2023).

To complement the IAPH framework, other academic works have emphasized models to assess port vulnerability and adaptive strategies. For example, Lam and Su (2015) analyzed disruptions across Asian ports and highlights that mitigation strategies often are dependent on pre-established contingency planning, data integration and infrastructure redundancy. Similarly, the work of Chowdhury and Quaddus (2016) emphasized on the dimensions of supply chain resilience in ports context, highlighting that organizational culture, cross-functional coordination and scenario planning enhances a ports capacity to absorb disruptions.

2.7 Digitalization in SMSPs

The level of digitalization in small and medium sized ports (SMSPs) varies widely. While the area is not significantly explored, evidence suggests that SMSPs often are lagging behind larger ports due to various challenges. Paulauskas et al., (2021) explore this using a mathematical model scoring 30 different ports in the Baltic, North and Mediterranean Seas regions based on their digitalization level. The results indicate that digitalization level in SMSPs is approximately 30% lower than that of large seaports. Similarly, the Swedish study by Lind, et al., (2021) confirms that many ports still handle information manually, with 52% lacking a formal digitalization strategy and only 35% utilizing a port management or community systems.

Both studies outline causes that hinder digitalization efforts, primarily related to financial, technical, and organizational limitations. According to Paulauskas et al., (2021) the main challenges are the lack of financial resources, expertise within the workforce, and limited access to advanced technologies and knowledge-sharing networks. According to Lind et al., (2021), there exists hindrance as there is often not a digitalization strategy in place, and insufficient in-house expertise. Another challenge is the fragmentation of digital initiatives, where interoperability with other actors across the supply chain is the main limitation. Additionally, outdated infrastructure and resistance to change among port stakeholders further hinder digital adoption.

Despite the lack of research on the level of digitalization there exist several studies on the challenges ports are facing in adopting digitalization. The studies support aforementioned challenges mentioned in the research. Additionally, it highlights barriers and hindrance relating to cybersecurity threats, data and security concerns, integration issues, regulatory and legal barriers and rapid market evolution challenges (Almeida, 2023; Brunila et al., 2021; Karlsson et al., 2023).

2.8 Digitalization & ITS role in Mitigating Disruptions in Ports

This section explores how digitalization and Intelligent Transport System (ITS) serves as targeted strategies that can mitigate disruptions in ports. Each category of disruptions is linked to technological innovation identified in literature as effective measures for mitigation. Table 2.2 summarizes these links, offering an overview of how specific solutions can address four categories of disruptions. Namely, natural, human-made, systematic, and financial, as classified by Ali et al. (2021). Although, some digital technologies often address other areas of disruption. For instance, a Port Community System (PCS) can be useful in mitigating both economical and systematical disruptions.

2.8.1 Natural Disruptions and Digitalization Measures

Natural disruptions, including extreme weather event and pandemics cause severe disruptions to logistics and supply chains (Ali et al., 2021), additionally, heavy wind and rain can cause slight disruptions in the form of tears on equipment and operational stops in ports. Research is mostly focused on disruptions to the supply chain, where it highlights responses to natural disruptions (Ali et al., 2021). It elaborates that automated disaster response platforms, IoT driven environmental and operational monitoring, and climate prediction models can significantly improve preparedness and response (Kleindorfer & Saad, 2005). Further, smart energy grids and sensor technologies enhance real-time monitoring and adaptive responses, which mitigates and reduces impact from natural disruptions (Ivanov & Dolgui, 2021).

2.8.2 Human-Made Disruptions and Digitalization Measures

Political instability, labor strikes, and security threats disrupt supply chain operations, which can be alleviated and mitigated by digital security and regulatory compliance solutions. Electronic Data Interchange (EDI) streamlines communication, while Port Community Systems (PCS) can enhance coordination. Further, blockchain can be utilized for regulatory compliance, and AI driven security improve risk management (Polemi, 2018). RFID access control and Automated Number Plates Recognition (ANPR) provides real-time security insights and prevents unauthorized access and ensures operational continuity (Scholliers et al., 2016). Further, digital workforce management systems can mitigate labor issues (Lam & Su, 2015)

2.8.3 Systematic Disruptions and Digitalization Measures

Systematic disruptions such as equipment failures, cyber-attacks, and power outages demand predictive maintenance and enhanced cybersecurity measures. Terminal Operating Systems (TOS) and Vessel Traffic Services (VTS) facilitate real-time monitoring, while IoT enabled predictive maintenance reduces the risks for equipment failures (Hervás-Peralta et al., 2019). AI-driven security measures including automated threat detection and response, which enhance protection against cyber threats (Polemi, 2018). Redundant energy systems, charging stations, and automated gate control provide mitigation measures in the form of reduced downtime (Yang, 2015; Zhang et al., 2024).

2.8.4 Financial Disruptions and Digitalization Measures

Economic fluctuations, bankruptcies, and volatile exchange rates can disrupt stability in operations of supply chain. Real-time RFID optimizes inventory and cash flow management. E-commerce platforms can facilitate trade and invoicing. Other measure includes digital platforms such as AI-enhanced financial analytics and blockchain-secured transactions which provide greater transparency (Cai, 2024).

Table 2. 2

Disruption Areas	*Causes*	*Impacts*	*Digitalization Measures for Mitigation*	*Sources*
Natural	Climate events (storms, floods), pandemics	Delays, infrastructure damage	AI-driven climate prediction models, IoT-based environmental monitoring, sensors, and smart energy grids.	(Yau et al., 2020; Lind, et al., 2021; Mithun Ali et al., 2021)
Human-Made	Political instability, protests, labor strikes,	Operational inefficiencies, security risks	Electronic Data Interchange (EDI), Port Community Systems (PCS), RFID for access control, digitalized customs process, blockchain for	(Bracke et al., 2021; Chao & Lin, 2017; Lehmacher, 2021; Moros-Daza

	security threats, port congestion.		regulatory compliance, Automated Number Plate Recognition (ANPR), time slot systems, automated gate control systems	et al., 2020; Nadi et al., 2022; Tsiulin et al., 2020)
Systematical	Fires, faulty equipment, power outages, cyber-attacks.	Data loss, breakdown of port operations	Terminal Operating Systems (TOS), Vessel Traffic Services (VTS), sensors and IoT for real-time equipment monitoring, AI-driven cybersecurity, redundant energy systems, charging stations, autonomous cranes, and gantry systems, digital twins.	(Bach et al., 2022; Gerlitz & Meyer, 2021; Hervás-Peralta et al., 2019; M. J. C. Samonte et al., 2024; Y. Yang et al., 2018)
Financial	Bankruptcies, limited cash flow, demand uncertainty and fluctuation	Reduced investments, financial instability	Port Community Systems (PCS), blockchain secured transactions, automated digital payment platforms	(Moros-Daza et al., 2020; Wang et al., 2019)

Table Categorization of Disruptions and Digital Mitigation Strategies in Ports.
Source: Own elaboration based on sources stated in the table.

2.9 The Port System

This section outlines the structural and institutional context of the Swedish port system. Beginning with an overview of the Trans European Transport Network (TEN-T) and its relevance for Swedish ports. Followed by a description of the Swedish port ownership structure. Lastly, it explains the criteria for selecting ports in this study.

2.9.1 Trans-European Transport Network (TEN-T)

Europe has an extensive coastline and a dense network of maritime trade routes, which relies on ports as strategic nodes in its transport infrastructure. Ports are key facilitator in moving good across regions and are vital to the functioning of the continent internal market and global trade. The European Commission has developed the Trans-European Transport Network (TEN-T) which identifies goals such as supply chain resilience, digital integration and efficient modal shifts. Further, the TEN-T framework encapsulates core nodes within the network that has to meet digital, multimodal and sustainability standards by 2030 (European Commission, n.d.). While the framework is not exclusive to ports, it constitutes critical access points and logistics hubs. The overall picture of the network can be seen in Figure 2.1 *TEN-T Core Network Corridors.*

Figure 2. 1

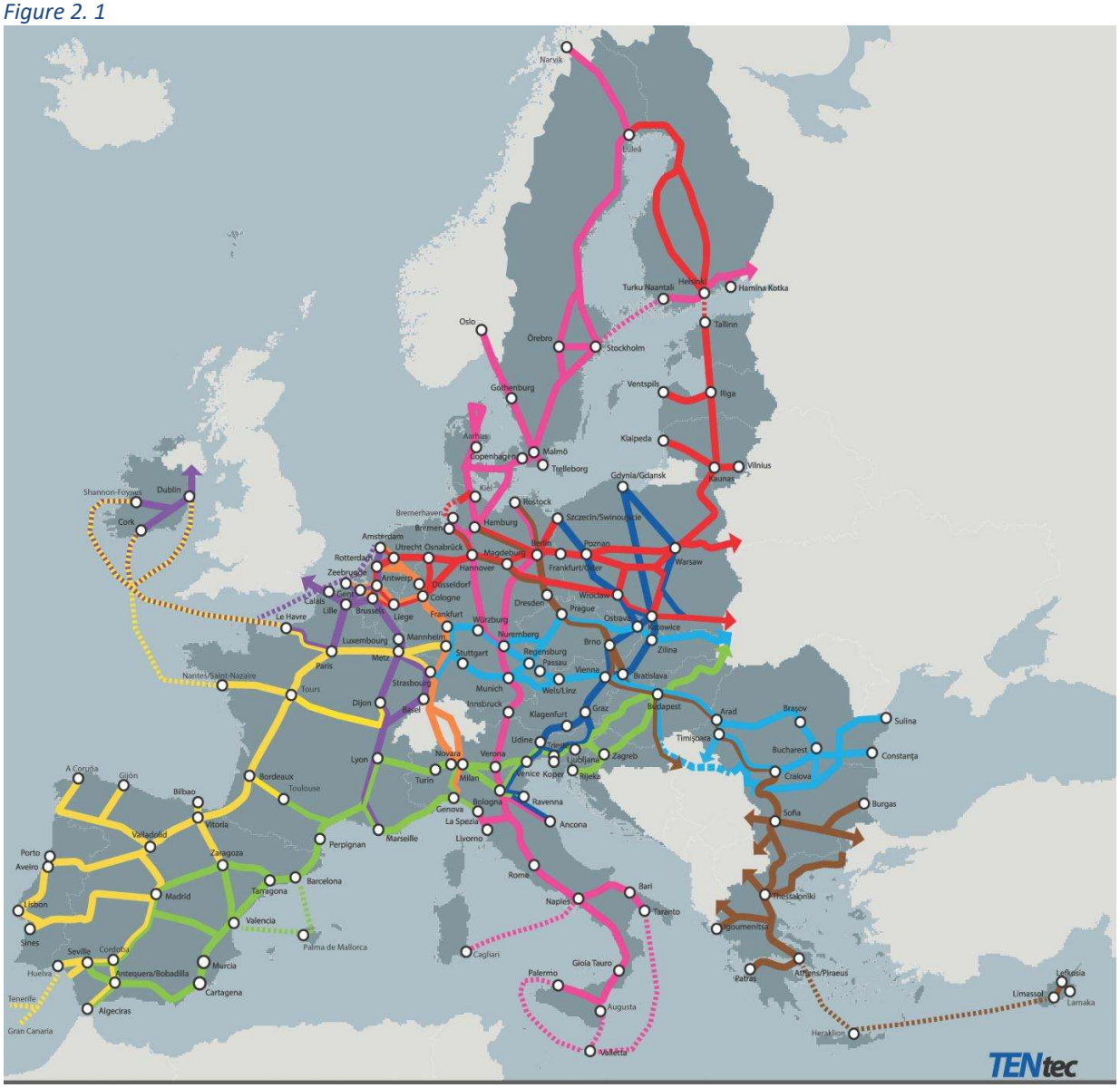

Figure 2.1. TEN-T Core Network Corridors. European Commission, 2024.

Sweden's integration within the TEN-T reflecting in the connection between Northern Europe with Central and Southern corridors, particularly through the Scandinavian–Mediterranean Core Network Corridor. There is several ports that have been identified as core nodes within the TEN-T such as Gothenburg, Trelleborg and Norvik. Further, there is several small and medium-sized ports (SMSPs) that functions as secondary and or complementary nodes. For instance, ports as Södertälje, Gävle, Norrköping and Oxelösund. These are classified as crucial feeder and regional distribution nodes within the network. In figure 2.2 the majority of ports included within the Swedish network is displayed, spanning from Gävle in the more northern part of Sweden to Trelleborg in the southern part.

Figure 2. 2

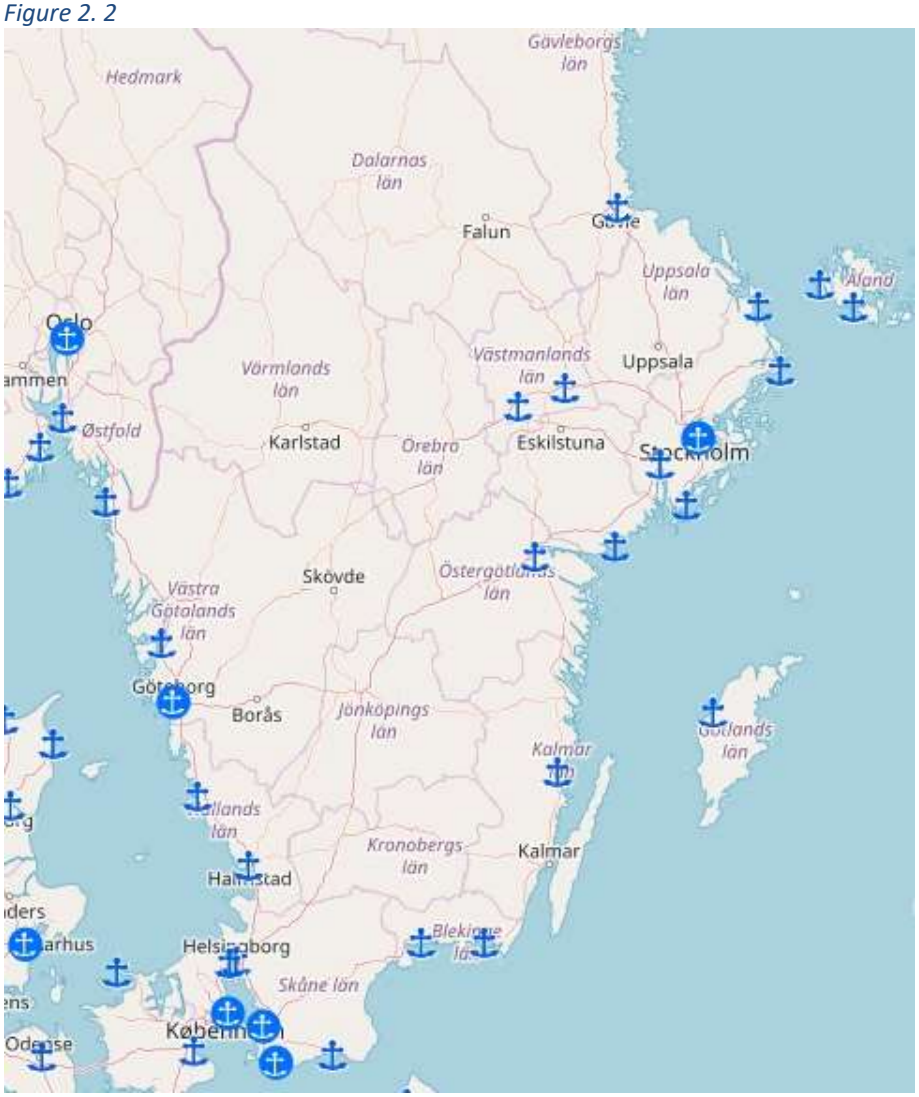

Figure 2.2. Selected *Swedish Ports within the TEN-T network*. Adapted from *TENtec Map Viewer*, by European Commission, 2024.

2.9.2 The Swedish Port System

The Swedish port system is distinctive in terms of its governance and ownership structure, which combines municipal ownership, private operations, and state oversight. The majority of the ports is owned and operated by the municipalities, typically through municipally controlled limited liability companies (Falkeby & Holm, 2010). This model enables ports to function commercially while maintaining strong ties to local infrastructure and business communities. This structure differs from many countries where most ports are controlled by the states. Although similar arrangements can be found in other regions, the predominance of municipal ownership in Sweden contrasts with the more centralized or state-controlled models common in many other European countries. Small ports are generally managed and operated directly by municipalities or their subsidiaries, whereas medium and larger ports often rely on

concession contracts, where terminal operations are managed by private companies under public oversight (Falkeby & Holm, 2010).

The Swedish state does not directly own or operate ports but has overall responsibility for maritime policy and infrastructure through authorities such as the Swedish Transport Administration and the Swedish Maritime Administration. While municipalities typically own the port terminals, the state retains authority over critical maritime infrastructure such as fairways, pilotage, and navigable waters, including the land and seabed surrounding port areas.

Investments in port infrastructure in Sweden are shared among various actors depending on port size and ownership structure. In medium and large ports, private terminal operators often finance and manage operational facilities, such as cranes and terminals, under concession agreements. In contrast, smaller ports may rely more heavily on municipal or state investments, especially for basic infrastructure. The Swedish state is generally responsible for financing and maintaining navigable waters, fairways, and inland transport connections. Ports that are part of the European Union's Trans-European Transport Network (TEN-T) may also receive EU funding, particularly for projects that enhance multimodal connectivity and integrate port areas into the broader European transport system (*Ägarstyrning av kommunala hamnar*, n.d.; *Trans-European Transport Network (TEN-T) - European Commission*, n.d.-b).

Private actors are playing an increasingly important role in Swedish ports, especially through terminal operations and logistics. For examples, some terminals are operated by international terminals such as the APM Terminals in the Port of Gothenburg which handles the movement of containers. Further, many port areas in the Port of Södertälje is operated independently by private companies in a public-private partnership (*Ägarstyrning av kommunala hamnar*, n.d.).

2.9.3 Selection of Ports

The ports selected for this study represent a group of small and medium-sized ports (SMSPs) in Sweden, all of which are municipally owned and classified as multipurpose ports, i.e, ports with varying kinds of traffic. Firstly, the ports are all part of the TEN-T network. Secondly, the ports are chosen due to their roles as regional logistics nodes capable of managing a variety of cargo type such as roll-on/roll-off (RoRo), dry bulk, liquid bulk, and project cargo which includes cargo that requires special handling due to unstandardized components. Lastly, the ports have similar characteristics of embeddedness within local and industrial transport networks. These factors align with the Port of Södertälje and enables a comparison between the ports. The selection includes ports such as Helsingborg, Hallands Hamnar (Halmstad), Norrköping, Trelleborg, and Oxelösund. In terms of quayside cargo throughput, the ports selected represents more than 40% of the total port traffic in Sweden for the year 2024

(*Hamnstatistik*, n.d.). These ports serve distinct geographical and economic regions and shares common challenges associated with SMSPs.

Although similarities, the operational contexts and digital maturity across the SMSPs are diverse. Therefore, it is essential to understand how each port has developed technological and infrastructural initiatives. The strategies for managing disruptions and implementing digital varies. Therefore, the following section presents an overview of these initiatives. It is categorized according to the four disruption types identified in the literature: natural, human-made, system-related, and financial. This categorization highlights the extent of digitalization efforts across different port environments and their contribution to mitigating disruptions.

2.10 The Port of Södertälje

The Port of Södertälje main function is to facilitate the movement of goods through their port and terminal operations. The ports operations are located on both sides of Igelstaviken in the city of Södertälje in the county of Stockholm. The port area is located approximately 2.5 kilometres from Södertälje's city centre. However, out of the different port areas, only the Igelstahamnen is located on the east side of the Igelstaviken. On the west side, the main area including the port areas of Sydhamnen, Bränslehamnen and Uthamnen is located. It is situated at the almost the top of Näsets Udde.

The reason why the Port of Södertälje and the city of Södertälje is closely interlinked is due to trade, transport, and geography. The city partially formed since it could act as a natural hub for shipping, situated in a narrow strait between Lake Mälaren and the Baltic Sea. Therefore, it has been a natural part of the city's economic well-being since the formation of the city. However, it was during the recent centuries it grew as an industrial city which enhanced the need for effective import and export of goods. Simultaneously, the canal of Södertälje was built and consecrated in 1819 and introduced a waterway which was open and passable. This canal was rebuilt and modernized again during the 1920s. Through the Södertälje Canal, ships could transport goods without having to go around the entire Stockholm archipelago. The same century the canal was built, the national railway track was laid through Södertälje. This further enhanced the interlink between city and port.

2.10.1 Port of Södertälje Services

The Port of Södertälje is a multi-purpose port of a relatively small size handling about 400 to 600 vessels annually. The vessels are relatively small due to the limited capacity of Södertälje Canal only allowing vessel up to 200 metres in length, 9 metres in depth and 32 metres in width. Primary, the range of vessels includes:

i. *Roll/on, Roll/off (RoRo) freight vessels*. These types of vessels are designed with a ramp which allows cars and trucks to be driven on and off the ship on their own wheels;
ii. *Lift/on, Lift/off (Lo/Lo) container vessels*. These vessels allow containers to be lifted on and off using a crane;
iii. *Bulk carriers*. These vessels a specifically designed transport cargo in bulk for example liquid bulk such as gasoline and diesel, and dry bulk such as grain;
iv. *Special and project vessels*. These vessels are designed to transport heavy or unique cargo that such as machinery or infrastructure components;

The port areas specialize in different operations. The port is divided as following:

i. *Bränslehamnen*. This is where liquid bulk is handled including gasoline, diesel, heating oil, asphalt etc.
ii. *Uthamnen.* In this area dry bulk and grain is primarily handled.
iii. *Sydhamnen.* In this area the primary container operations are located, the project cargo, as well as the vehicle import.
iv. *Igelstahamnen.* This area handles wood chips, peat and similar goods for Södertälje's combined heat and power plant.

The port offers other services including:

i. *Rail connection*. The port has direct connection to the railway network with the possibility to load and unload container and bulk directly on trains.
ii. *Truck logistics and warehousing.* The port has services for intermediate storage and transhipment of goods.
iii. *Towing and assistance.* This includes services to manoeuvre in and out of the port.
iv. *Waste management.* This includes reception of waste, including oil residues and hazardous waste.

2.10.2 The *Green Gods Hub* Development Plan

The port of Södertälje's recent (2023) development has been as part of the project of Green Goods Hub. The project is in turn a derivate of the grant agreement made by the European Climate, Infrastructure and Environment Executive Agency (CINEA) together with Södertälje municipality. The grant agreement clearly outlines the action, estimated budget, as well as information about potential expenditure, liabilities and other financials of the project. The laid-out plan was and still is to strengthen the port of Södertälje through research about necessary investments which is the condition and motivation for where to allocate further spending. The aim is to develop the port of Södertälje as a key hub of logistics and transport in the Stockholm

Region, in line with and part of TEN-T policies to achieve a higher level of sustainability, less reliance on fossil fuels and increased integration of multimodal transportation. This will be achieved through developing the key areas of Infrastructure. Through the infrastructure investments, the goal is to remove bottlenecks, making changes to accommodate bigger vessels and increase intermodal transport by connecting and improving road, rail and inland waterways. Through means of electrification the goal is to create a supply of shore side electricity and electrify rail freight. The project of the Green Goods Hub, in partnership with CINEA and through CEF (Connecting Europe Facility), and as part of TEN-T will span three years having started May 1, 2023, ending April 30 of 2026 (personal communication, n.d.).

3. Methodology

This chapter outlines the methodological approach used to explore how digitalization and Intelligent Transport Systems (ITS) contribute to resilience and operational efficiency in small and medium sized ports. It describes the research approach, philosophical foundations, design, data collection procedures, sampling strategy, the analytical process as well as addressing ethical considerations and limitations.

3.1 Research Approach

Research approach refers to the strategy and reasoning behind how knowledge is generated and interpreted within a study. According to Collis and Hussey (2014), research approach can be generally classified into inductive, deductive and abductive. A deductive approach often follows a top-down reasoning process moving from a theory or hypothesis to test it using empirical data making specific observations. An inductive approach follows a bottom-up reasoning process where research begins with specific observations or data collection, leading to development of patterns, themes or theories. An abductive approach combines element of both and allows for research to move between data and theory iteratively to develop explanations. The reasoning often starts from an incomplete set of observations and seeks the most plausible explanation by integrating empirical findings with existing theories.

This study adopts a primarily inductive approach with elements of abduction, aligning with the exploratory nature and pragmatist research philosophy. Since there is limited research on digitalization in SMSPs, particularly the Port of Södertälje, an inductive approach allows for a data-driven exploration of how digital tools, specifically ITS contribute to operational efficiency and resilience. The study seeks to build an understanding from empirical data and allow for patterns and themes to emerge. Through qualitative methods such as semi-structured interviews, a survey, case study, and document analysis, the study aims to develop a contextualized understanding of Södertälje Port's digitalization transformation. While the inductive approach forms the foundation of this research, element of abductive reasoning is incorporated to ensure a balanced engagement between empirical findings and existing theories. As data is collected analysed, connection to existing theories on digitalization and resilience will be explored. Thus, rather than rigidly applying theoretical constructs from the outset the allows for emerging insight to guide the interaction with theory, explanations, and conceptual models.

3.2 Research Philosophy

Research philosophy refers to the underlying assumptions and beliefs that guide the research process, influencing the choice of methodology, research design, and data collection techniques (Collis & Hussey, 2014). Therefore, it provides a framework for how knowledge is perceived and how the researcher engages with the matter of subject. Understanding what role research philosophy have enables a coherence between research objectives, methods and expected outcomes. Thus, allowing for a structured and justifiable approach to research contribution. Collis and Hussey (2014) outline key paradigms, including positivism, interpretivism, realism, and pragmatism. Positivism is grounded in objective reality, favouring quantitative methods and generalizable results. Interpretivism emphasizes subjective experiences and qualitative insights. Realism balances the two former perspectives acknowledging both observable phenomena and deeper underlying realities. Pragmatism allows for methodological flexibility and focuses on solving practical problems rather than strictly adhering to one epistemological stance.

Pragmatism is the most suitable research philosophy for this study because it aligns with the practical and solution-oriented nature of investigating how digitalization and Intelligent Transport Systems (ITS) enhance resilience and operational efficiency in Swedish small and medium-sized ports (SMSP), particularly the Port of Södertälje. Unlike positivism, which emphasizes objective measurements, or interpretivism, which focuses solely on subjective meaning, pragmatism prioritizes real-world applicability and problem-solving (Collis and Hussey, 2014).

In the context of the Port of Södertälje, digitalization is a dynamic and multi-stakeholder process, where different actors such as port authorities, logistics operators, and technology provides experience and interpret technological advancements differently. Therefore, a pragmatist stance enables the study to explore these perspectives in a practical and actionable manner. Focusing on how digital solutions function in practice, and how they can be improved rather than theorizing about their role. Further, the goal of this research is not just to understand digitalization in SMSPs. Instead, it aims to provide recommendations for the Port of Södertälje's future strategies. Pragmatism supports this applied focus as it allows the research to extract practical insights from qualitative and quantitative data without being limited by one philosophical stance. Overall, it enables a balancing between empirical insights and real-world applicability, ensuring that the findings can contribute to both academic understanding and practical decision-making in port digitalization and resilience strategies.

3.3 Research Rationale

A key question any researcher must ask before undertaking a study is whether the research is relevant and necessary (Cohen et al., 2018). Digitalization in SMSPs is an ongoing and evolving process structured around technological advancements and regulatory pressures. While large ports have made significant strides in ITS adoption, SMSPs often lag due to resource limitations, fragmented digital strategies, and interoperability challenges. Therefore, this research aims to examine the current digital landscape of Swedish SMSPs and at the Port of Södertälje, asses its alignment with industry standards and best practices, and identify areas that require further digital development. Thus, the research will serve as a resource for port authorities, policymakers, and industry professionals to understand the current state of digitalization in SMSPs, and the pathway for development.

By exploring how digitalization and ITS contribute to operational efficiency and resilience, this study aim to provide an analysis of the Port of Södertälje's current digital maturity. As ITS solution are increasingly driven by industry and customer demands, this research considers the perspectives of stakeholder. Understanding their expectations, challenges, and needs will offer valuable insights into how digitalization can be leveraged to improve service reliability and disruption management.

Given Sweden's strategic goals for digital transformation and the alignment with the Trans-European Transport Network (TEN-T) digitalization targets, the practical recommendations from the study will focus on enhancing digitalization and ITS capabilities, more efficient integration with hinterland transport networks and the need to meet regulatory expectations.

3.4 Research Design

The research employs a mixed-methods research design to investigate the impact of digitalization initiatives, particularly ITS, on enhancing operational efficiency and resilience in Swedish SMSPs. According to Collis & Hussey (2014), qualitative research is characterized by its interpretative and exploratory nature, enabling research to investigate social and organizational phenomena in depth. The qualitative research component consists of semi-structured interviews with key stakeholders in the Port of Södertälje. These interviews are guided by themes derived from the literature review and are analysed using thematic analysis. This it allows the research to be flexible in methodology and generate insights that can inform action. It is useful to not only understand the subjective experiences of stakeholder in the Port of Södertälje, but also to derive practical recommendations.

To complement and extend these findings, qualitative component is integrated in the form of a structured survey. The survey is designed around scenario-based prompts and collect

numerical and categorical data concerning respondents' expectations and assessments of digitalization potential impact under different conditions. This enables a comparative assessment across hypothetical best, moderate and worst-case scenarios. The rationale for the mixed-methods approach stems from the ability to bridge what is currently practiced and perceived through interviews, and what might be anticipated through surveys. It enhances the exploratory research philosophy as it ensures depth and generalizability.

A case study approach is employed, focusing on SMSPs and Port of Södertälje as a representative navigating digitalization. Case studies allow for holistic examination of organizational processes, stakeholder perspectives, and external influences (Collis & Hussey, 2014). However, the research design integrates multiple data collection techniques, semi-structured interviews, surveys, document analysis, and observational data. By triangulating these data source, it can ensure a comprehensive understanding of how digitalization influence operational efficiency and resilience in SMSPs.

3.5 Primary Research

Primary research is conducted to collect firsthand empirical data, providing specific insights into digitalization initiatives at the Port of Södertälje. Given the study's mixed-methods approach; firstly, the primary research focuses on gathering organizational perspectives and operational insights through direct engagement with key stakeholders. Secondly, the primary research is structured around quantitative and qualitative data collection methods, and a case study approach.

3.6 Secondary Research

Secondary research involves the collection and analysis of existing data from academic literature, industry reports, policy documents, and relevant case studies. This approach allows for the study to build on established knowledge while identifying gaps that require further empirical investigation (Collis & Hussey, 2014). The study employs several secondary sources including academic literature, industry reports, policy frameworks, and case studies. The secondary research supports the contextualization of digitalization efforts at the Port of Södertälje and helps establishing benchmarks and current state of practices in the industry.

3.6.1 Qualitative Research

The qualitative research is used to explore how and why digitalization initiatives impact efficiency and resilience at the Port of Södertälje. It allows for in-depth insight into stakeholder perspectives and experiences, and for the flexibility to explore emerging themes in the industry. Additionally, it supports an exploratory approach identifying patterns and relationship that may

not be evident in quantitative data (Collis & Hussey, 2014). The primary qualitative data collection method utilized in this research is interviews with actors within and connected to the Port of Södertälje.

3.6.2 Interview Design

The interviews are semi-structured and are the primary data collection method, allowing for a balance between structured inquiry and open-ended exploration. This format provides consistency across respondents and allows for flexibility to investigate deeper into emerging themes during the interview (Collis & Hussey, 2014).

3.6.3 Target Population

The target population for this study consist of key stakeholders involved in the operations, management, and digital transformation of the Port of Södertälje, as well as other relevant actors within the Swedish small and medium-sized port ecosystem. The target population being private actors, contributes to an understanding of how digitalization and disruptions are perceived and managed by these private and external stakeholders. These stakeholders include:

i. *Logistics and Transport Operators.* Freight forwarders, shipping companies, and inland transport operators that interact with the port's digital infrastructure.
ii. *Major industrial customers.* Large manufacturers and shippers that rely on the port for their supply chain operations.
iii. *Industry Experts.* Researchers and professionals with expertise in port digitalization and transport management.

3.6.4 Sampling

A purposive sampling method is utilized to ensure that the most relevant and knowledgeable individuals are selected for the study. According to Collis and Hussey (2014), purposive sampling is a non-probability sampling technique in which the research intentionally selects participants for the study based on specific characteristics such as expertise and knowledge. It is useful when a study needs a target population that can provide a rich, relevant, and in-depth insights. The study conducted 6 semi-structured interviews. The participants will be based on their expertise and role, organizational representation, and relevance to the Port of Södertälje.

3.6.5 Quantitative Research

Quantitative research was utilized as a complementary method to encapsulate broader perspectives on digitalization and operational resilience. The survey was conducted following the interviews and was designed as structured questionnaire collecting responses on a one to five Likert scale. Except the last question which collected a qualitative response on desired digitalization efforts in the future. The survey respondents were the same range of stakeholders as in the qualitative research. The results were analysed descriptively to identify general trends and common challenges within the sector.

3.6.6 Survey Design

A total of 6 respondents participated in the survey, representing professional roles within the logistics, transportation and port environment sectors. Their responses provided valuable insights into a forward-looking perspective. The survey consisted mostly of close-ended questions, utilizing a five-point Likert scale to capture the degree of likelihood, perceived risks or agreement with statements. The findings offer a foundation for analysis of current attitudes toward digitalization. Additionally, the results serve as input to the scenario development process.

3.6.7 Participant Demographics

The survey respondents were represented by the respondents in the interviews. Participants included individuals working within operations management, logistics coordination and digital infrastructure development. By involving the same group of stakeholders, the research allowed for deeper and more consistent exploration of their perspectives. Given that the respondents had prior engagement through interview, the respondents were already familiar with the research topics and themes. Thus, it contributes to the relevance of their survey responses. Their professional background covered both technical and managerial domains which ensures that it provides a comprehensive view of operations and strategic consideration in relation to digitalization.

While no demographic data such as age, gender or formal education was collected in the survey phase, the diversity of professional roles were established during the interview phase. Through purposeful sampling it strengthens the reliability of the empirical materials.

3.7 Data Analysis

The data analysis in this study follows a mixed-methods logics of integration. The qualitative data and quantitative data are complementary to produce a nuanced understanding of digitalization role in logistics performance in small and medium-sized ports. Each data type is

analysed separately using strategies and then synthesised in the construction of scenario-based findings.

The qualitative data from interviews are analysed using thematic analysis. It is guided by the approach in the literature of Collis and Hussey (2014). Collis and Hussey (2014) describe that thematic analysis is a method for identifying, analysing and reporting patterns or themes within qualitative data. It enables the research to interpret key features related to the research questions. Therefore, through coding the data inductively one can identify themes that capture how digital tools are understood, implemented and experienced across industries, organizations, and roles. In the study, each interview was reviewed and coded with statements and concepts categorized into initial themes. Secondly, these initial codes were iteratively refined through comparison across interview to identify recurrent patterns, contradictions and emerging insights. The results provided the dimensions "*resilience and response to disruptions*", "*information flow and interorganizational collaboration*", and "*digitalization and ITS implementation*". These themes provide a foundation for the scenario narratives and enables highlighting of tensions, expectations and perceived opportunities linked to digitalization in relation to resilience.

The quantitative data from the survey are analysed descriptively to identify patterns in how different participants responds to hypothetical scenarios. While statistical generalization is not the aim, the survey enables a structured comparison across actors' groups and scenario types. The data is utilized to assess how expectation vary between organizations and roles, and in relation to operational efficiency and digitalization.

3.7.1 Scenario Analysis

Both research data, interviews and survey responses are integrated through a scenario analysis framework. Research has shown that scenarios can be useful in addressing complex and uncertain context and producing intriguing finding (Ramirez et al., 2015). The study utilizes the thematic findings from the interviews to provide contextual foundation for each scenario, while the survey data is utilized to supply inputs that shape how actors anticipate the effects of digitalization. The synthesis enables a development of three exploratory scenarios; best-case, moderate-case, and worst-case. Each represents a distinct setting of operational efficiency, resilience and digitalization. The scenarios are not predictive but serves as an analytical tool for mapping potential trajectories and organizational readiness. Drawing on principles of exploratory scenario methodology (Ramirez et al., 2015) and triangulating semi-structured interviews and the stakeholder survey, the analysis ensured that the scenarios reflected an understanding of current challenges, stakeholder uncertainties and strategic

trade-offs facing Swedish SMSPs. The scenarios illustrate different outcomes that depend on different strategic choices regarding digitalization and collaboration.

3.8 Ethical Considerations

This study adheres to established ethical principles involving human participants, such as issues of informed consent, confidentiality, data protection, and the voluntary nature of participation. These considerations are consistent with research provided by (Collis & Hussey, 2014) on research within management. It emphasises on the importance of transparency, respect for participants, and integrity throughout the research process.

Firstly, all participants were provided with clear and comprehensive information about the purpose of the study. Including the academic context and how the data would be used. Secondly, the participation in the interviews and survey was entirely voluntary, and informed consent was obtained prior to the data collection. This included a statement that the participants had the right to withdraw at any time without consequence.

Thirdly, the anonymity of participants and confidentiality of data have been preserved. All interview data were anonymized, and all organizational references were removed. Accordingly, the data were stored on devices only accessible to the researchers. This aligns with the principles of Collis and Hussey (2014) on protecting the participants identity particularly in organizational context where relationships and reputational risks may arise.

Fourthly, endeavours were made to respect the time and dignity of participants as foundational ethical commitment. To allow for reciprocity, all participants were offered a summary of research findings and were invited to give further clarification or feedback. Moreover, transparency, was maintained by clearly communicating the purpose and potential implication of the study. Since the professional and strategic roles of participant includes several senior or operational roles in logistics and transport sectors it was important to navigate relational ethics carefully. The questions were designed to be theoretical, aligning with the broader industry standards, to avoid reputational harm or disclosure of commercially sensitive information. This aligns with Collis and Hussey (2014) stance on mutual respect and integrity in business research relationships.

3.9 Validity and Reliability

This research is guided by a pragmatic philosophical stance, which emphasizes methodological pluralism, practical relevance and the production of useful knowledge. This entails that validity and reliability are conceptualized in terms of credibility, transferability, dependability and confirmability (Collis & Hussey, 2014).

The study employs a mixed-methods approach where thematic analysis of qualitative interview data is combined with quantifiable survey to produce a scenario analysis. This offers a depth of understanding and scenario-based foresight. Further, it strengthens the pragmatic validity of the research as each method contribute complementary forms of insights to address a complex research problem.

Credibility refers to the extent which the findings accurately represent the participants perspectives (Collis & Hussey, 2014). The was ensured by conducting semi-structured interviews with multiple actors across the port and logistics ecosystem, and by providing rich descriptions of their accounts in the findings. Credibility was further supported by continuous engagement with the data through an iterative development throughout the process. It ensured that the insights were not imposed on the data but co-constructed in relation to the stakeholder experiences.

Transferability refers to the applicability of findings beyond the immediate research context (Collis & Hussey, 2014). Although the primary focus is on the Port of Södertälje, the strategic similarities between small and medium-sized ports (SMSPs) across Sweden and partly Europe allows for analytical generalisation. Particularly regarding digital capacity, operational vulnerabilities, and stakeholder fragmentation. The contextual description of the case, actors and processes provides the necessary depth for readers to assess relevance to other port systems.

Dependability refers to the consistency and logic of the research process (Collis & Hussey, 2014). To ensure dependability all steps of data collection, coding, theme development and scenario designed has been documented. Further, the study's methodological logic has been ensured through the use of method choice and analytical procedures. Moreover, the scenario analysis follows a documented and traceable logics where key variables, assumptions and input parameter were derived from both qualitative and quantitative methods. This ensures consistency between the interpretive and simulation-based component of the study.

Confirmability refers to the degree to which findings can be traced to their sources rather than to researcher bias (Collis & Hussey, 2014). The use of reflexivity was used as a strategy to examine the research own assumptions and influence throughout the process. Furthermore, the mixed-methods approach combined with the scenario-analysis allows for a form of triangulation which strengthen confirmability by allowing the research to test findings under varied operational conditions. This enhances the robustness and relevance of the study's conclusion.

3.10 Limitations

While the mixed-method approach provides a holistic understanding of the research it simultaneously introduces specific limitations which is important to consider. The research is mostly structured around a single embedded case study of the Port of Södertälje. Although, it represents an example of SMSPs in the Swedish context, and is strategically relevant due to its location, multi modal integration and stakeholder complexity. However, case study research is limited by design through statistical generalisability (Collis & Hussey, 2014). The insight may resonate with similar ports, but factors such as regional planning policies, existing infrastructure, or stakeholder constellations should be considered when transferring findings elsewhere.

The qualitative method of the study further introduces some limitations since semi-structured interviews are inherently interpretive and shaped by participants perspectives and the researcher framing (Collis & Hussey, 2014). While steps have been taken to ensure credibility, the themes constructed are situated interpretations and not objective truths. Furthermore, the sample may not capture the full diversity of perspectives across the port ecosystem, particularly voice from operational or labour-level roles. Additionally, some potential candidates for the sample such as third-party logistics companies and shipping companies abstained from participating, limiting the insights.

The quantitative method of the study is valuable in supporting triangulation and mapping broader attitudes. However, it faced constraints such as limited response rates and possible self-selection bias. Meaning, that respondents who participants may have been more engaged with the subject or inclined to answer more than the general population of the sample. Additionally, the survey focuses on perceptions and readiness rather than performance metric, which limits its ability to quantitatively assess the casual impact of digitalization on resilience (Collis & Hussey, 2014).

The scenario analysis forms the forward-looking component of this study and thus the recommendations, and it should be noted that this rests on simplifying assumptions. This includes projected trends, stakeholder behaviour under uncertainty, and estimated technological impact. While it is grounded in the quantitative and qualitative data, the scenarios are not predictive models. Rather, the scenario should be seen as tools for structured reflection and exploration. Moreover, the strength lies in provoking strategic thinking rather than delivering probabilistic outcomes. Furthermore, resources constraints hinder the application of more advance simulations techniques such as digital twins or system dynamics.

The study utilizes a mixed-method structure with a strength stemming from the depth and triangulation. However, it proposes integration challenges. Since not all emerging themes from the qualitative analysis where directly reflected in survey design or scenario dimensions. Moreover, some findings that are latent dimensions from interviews are less quantifiable and therefore less integrated into the scenario models. This highlights a trade-off between interpretive richness and strategic generalities.

A notable limitation is the sensitive classification of the port as it is a national security object. This status entails restrictions on the disclosure of certain operational, infrastructural, and digital systems information. Therefore, detailed descriptions of technologies, protocols, or systems architecture cannot be fully explored. Further, some interviewees are limited in what they can share. While this may have affected the granularity of the data, the research was designed and ethically conducted to respect these conditions, ensuring validity and credibility within the permissible scope. The study still provides valuable insights into digitalization and resilience practices from the perspective of private stakeholders.

4. Empirical Findings

This chapter presents the empirical findings from the categorization of initiatives in Swedish SMSPs, the interviews with stakeholders of the Port of Södertälje, as well as the follow-up survey results.

4.1 Findings - Initiatives in Swedish SMSPs

This section categorizes the various initiatives implemented in Swedish SMSPs, focusing on how these ports mitigate different types of disruptions through digitalization measures. The categorization builds upon the four-part disruption typology outlined earlier in Table 2.2, which classifies disruptions into natural, human-made, system-related, and financial categories. It aligned digitalization technologies with these disruption types. In Table 2.2, it provides a comparative view of how Swedish SMSPs interpret, prioritize, and operationalize resilience through digitalization. This approach relates to our first research question and supports the objective of assessing how digital tools are leveraged to enhance resilience in the context of Swedish SMSPs.

Table 4. 1

Port	*Natural Disruptions*	*Human-Made Disruptions*	*System Disruptions*	*Financial Disruptions*
Hallands Hamnar (Halmstad)	CO2 capture, wind power project	Automated gate control, smart sensors	TOS (Portit), Charging stations, AI pilot, Electrified reach-stackers.	
Helsingborg	IoT pilot (noise and emissions),	Automated custom clearance, automated gate control, ANPR, autonomous vehicles pilot, positioning systems for cranes	TOS (Navis N4), electrified reach-stacker and trucks, digital twin, internal and public charging stations, electrified tug,	
Trelleborg	Wind power,	RFID access control, Automated gate control, ANPR,	TOS (Hogia) Camera and sensor for measuring operations, charging stations,	
Gävle	CO2 capture,	Time slot system	TOS, Charging stations for trucks, port activity app, electrically powered gantry cranes, VTS,	
Stockholms Hamnar		Automated gate system, Truck appointment system (time slot)	TOS (nGen), Automated cranes and gantry systems, fleet management system, electric machinery (straddle carrier, small trucks)	

Oxelösund	CO2 reduction (By Awake.AI)		TOS, ICT Tool (By Awake.IA)
Mälarhamnar		Workforce management platform	TOS (Hogia),
Ystad		Digital Mobile Radio (DMR)	TOS (Hogia), simulation pilot
Karlshamn	Wind power project		TOS (Hogia)
Norrköping	CO2 reduction (By Awake.AI)	Workforce management platform, smart port calls,	TOS, ICT Tool (By Awake.IA), PCS, electrified machinery,
Piteå	Smart port office (Sensors, solar)		TOS, PCS, ICT,

Table 4.1. Categorization of Initiatives in Swedish SMSPs. Sources: (BMG, 2025; *Gävle Hamn - Mellansveriges Logistiknav*, 2025; *Hallands Hamnar - Hallands Hamnar*, 2025; *Helsingborgs Hamn - Containerspecialisten*, 2025; *Karlshamns Hamn*, 2025; *Mälarhamnar AB - Våra hamnar i Västerås och Köping*, 2025; *Oxelösunds Hamn - Djuphamn vid Östersjön*, 2025; *Port of Piteå*, 2025; *Port of Ystad*, 2024; *Stockholm Norvik Hamn - stockholmshamnar.se*, 2025; *Trelleborgs Hamn – Skandinaviens största RoRo-hamn.*, 2025)

The categorization presented in table 4.1 is based on externally observable initiatives and available documentation as per a literature review. However, internal functioning of terminal systems across Swedish SMSPs remains questionable due to various amount of standardization, system documentation and data-sharing practices. Consequently, the classification may not fully capture functional depth or integration levels that interact with terminal systems. Similarly, security systems and their level of integration has little to no information available.

4.2 Interview Findings

Participants in this study are from a diverse range of organization and roles within the port ecosystem. This includes automotive manufactures, energy providers, third-party logistics, and shipping companies. The professional experiences of the interviewees range from logistics planning, project coordinator to digital transformation strategies, with many holding senior roles in supply chain operations. The results are organized according to the themes outlined in the interview guide, covering the port, information exchange, disruptions, resilience and digitalization.

The experience among the interviewees relating to digitalization varied notably. Several participants described their companies as digitally advance, with internally integrated enterprise systems and structured workflows. However, a recurring sentiment among participants was the asymmetry between digital capacities within their own organization and the systems in place at the port of Södertälje. One interviewee stated that, *“I’ve been working with logistics for over 15 years and seen firsthand how slow our sector is to embrace digital*

tools." On the other hand, some interviewees downplayed the significance of digitalization in their own role. For instance, one interviewee stated that while their company had invested in digitization, their function was not reliant on such tools and therefore "*it didn't make much different day-to-day."*

Some respondents were directly involved in implementing digital systems while others expressed limited engagement. An interviewee explained that "*we've recently integrated a TMS that helps us sync better internally, but that's still disconnected from our work with the port*". Overall, the knowledge of digitalization was heterogenous in nature, and it determined how participants experienced cooperation with the port.

4.2.1 The Port

The port was most often described as a reliable but operationally limited actor. Several respondents emphasized the value of geographic proximity and personal contact. An interviewee stated that "*we work closely with the port – and on paper everything is okay, but things can often fall apart when you need quick answers*." Another respondent praised the familiarity of collaboration stating that "*they know our routines, which helps*." Where the sentiment was further enforced by another interviewee that stated, "*if nothing needs to be communicated, it's a good thing*".

At the same time, capacity constraints and infrastructural limitations were frequently cited. According to on interviewee discussing freight, stated that, *"Sometimes we have the goods ready, but there's simply no room at the port."* One interviewee explained that although they understood the ports space issues, the lack of flexibility forced them to maintain larger buffers in upstream planning. Further, one of the respondents mentioned "*ports are always inflexible and cannot accommodate for the needs of our product".* This was in relation to their production schedule and critical lead times.

However, not all respondents found these aspects as critical. For instance, one interviewee stated that "*the collaboration works well enough for our needs – we are not pushing huge volumes, so we don't notice any bottlenecks.*" Therefore, the relevance of such challenges or delay may depend on operational scale and frequency.

In terms of opportunities, multiple actors highlighted the ports' strategic location and their willingness to use it in their supply chain. For instance, one interviewee stated, "*It's a small port, but it's close to everything that matters - Stockholm, industry, distribution centers*."

4.2.2 Information Flow

The answers for questions regarding information flow is a segment in this study that is varied between the different interviewees, there was a general agreement that information flow serves as an important role of making the port and its partnerships with actors works well, however the degree in which how important, and the different challenges and opportunities that exists was more nuanced.

The current level of information flow that was expressed by most interviewees can be summarized as basic but sufficient. And the key challenges seen by most interviewees is explain as indirect, fragmented and lacking strong real time accuracy and transparency. Throughout the answers the basic nature of it is described, with strong themes around the use of manual communication methods such as email and phone, instead of integrated digital systems. Several actors highlighted the basic nature of the tools use, one interviewee stated, "*It´s all very manual, email and phones."*

The indirect nature of the current information flow experienced by the interviewees and the fragmented communication channels can be described by a multitude of answers, such as*, "We communicate very, very rarely directly with the ports […] instead it goes through a carrier or a shipping line."* And *""We may not always have direct contact with the Port of Södertälje [...] it goes through the party purchasing the service."*

Another actor felt that there was a lack of available information, and that this is one of the core challenges for them in terms of their processes with the Port of Södertälje. The same interview expressed problems of late information, a lack of sufficient information sharing channels as well as a lack of data gathered, *"Information sometimes only is known after the ship has left", "We see that we don't always have platforms or IT support that consolidate all information in one place",* and *""Yes, we would need to work more with information, like wanting EDI connections or that we share information with each other. That, that's what I see as the big thing."*

These quotes presented above give light to the current challenges in information flow, but as mentioned the consensus from interviews are that despite these challenges and the basic nature of the processes it works on a sufficient level. One actor described the information flow as *"The way communication works today – it works well. Everyone is good at responding and it all moves quickly."* And another actor as *""We have a weekly meeting where we talk about things... It's really good. It actually works great when we bring all the actors together."* Showing that despite the basic nature of the current information flow, and the processes that is part of it, it meets the needs of most of the actors' interviewed needs.

When asked about improvements, participants pointed to existing solutions in other ports "*we don't need anything fancy, just something that lets everyone see the same thing at the same time."* Others mentioned interest in shared dashboards or predictive arrival systems, though noted that cost and standardization were major challenges.

4.2.3 Disruptions

Disruptions was an area that the actors interviewed felt were important and effected their operations. Every actor is affected by disruptions, and some worried more than others about how these impacted the company and their operations. Disruptions were discussed and showed up in several forms such as port congestion, mismanaged planning and weather-related issues etc. However, the actors considered these as a major challenge when they occur, but because of their relative rare occurrences did not view them as daily obstacles to consider in their daily operations.

A recurring disruption that was mentioned was the sometimes-limited space relating to systematic disruptions. For example, one interview explained *"We have grown in volume, but not one additional square meter of space has been added to the port"*. And another one said, *"Sometimes we have the goods ready, but there's simply no room at the port."* This leads to bottlenecks in the supply chain that results in further planning and change of strategy for routing and workarounds. This lack of space and capacity was also felt by one actor specifically. In this case, another actor entered partnership with the port, leading to a customer of the port deliveries being under prioritized, and through this lack of space had to compete with this new actor. This disruption was caused by a misjudgement of volume and planning, and the results of this is showed in the quote: *""We had a plan for our deliveries […] the entire schedule was changed. That destroyed everything for us."*

Further, another systematic disruption was unclear responsibility for damages. An interviewee raised concern "*there's always a discussion about who bears responsibility. Did it happen before it arrived to the port, in the port or onboard the vessel.*" Further, he stated that in other ports their goods are subjected to digital solutions such as high-resolution imaging systems and suggests this as a mitigating measure "*we have talked about possibly installing cameras at entry point to capture images of trailers or whatever it is, soe we can see whether it was damaged when it came in or if it was intact.*" The disruption lies in the failure of the system to clarify, document, and resolve the issue efficiently.

Other disruptions expressed was weather, labour availability and geopolitical. Weather is seen a disruption, but it was not regular enough and the impact usually not major. *"If the weather is bad, sometimes you have to wait four hours or postpone the trip"*. Another disruption was lack

of labour and support services. This highlights the lack of pilots, as quoted by one interview: *"the pilot wasn't available, so we couldn't bring the ship in"*. Disruptions in the supply chain and general geopolitical instability was also mentioned as a challenging disruption, however this was mostly relevant for actors with international freight, *"We have to handle logistics and accept the challenges that come—war, terrorism, rerouting, restrictions… It all affects costs, delays, and planning."*

Solutions to these disruptions were also discussed, such as changing the mode of transport *"Sometimes we shift to air freight if something is delayed, especially if it's urgent or needed for production."* Or operational changes to account for the disruptions such as through buffer stock *"We build in some buffer time and extra material in the upstream planning, just in case something goes wrong."*

The actors interviewed generally saw disruptions as a natural part of their operations and as a part of logistics. With this the actor's strategies and operations heavy focus on flexibility, manual coordination and previous experience instead of structured resilience systems or predictive tools. The interviewees all agreed that the port of Södertälje generally function well to handle disruptions, however that the main challenges in disruptions are usually caused by a lack of infrastructure, labour availability and inefficiencies in information sharing and communications. Organisational and human factors are the causes of the majority of the disruptions mentioned as the biggest challenges throughout the interviews.

4.2.4 Resilience

The term resilience was a term that was not always address directly by the interviewee, however there emerged several themes that showcases how the actors navigate through disruption, uncertainty and their ability to adapt to the changing conditions. The interviews showed that the actor's approach to resilience and their understanding as more informal and a reactive one instead of a proactive one. To be able to handle, adapt and recover their operations and functions in a disruption event, the most important aspects were flexibility, experience and coordination.

One interviewee explained their view of resilience as *"It's the ability to adapt to a reality that isn't always fully known"*. And this shows both the understanding of the term but also this interviewee approach to it, specifically that the reality isn't always fully known. This illustrates a key point, that actors understand the need to change however few have plans or systems anticipating for it, showcasing the reoccurring theme of having a reactive approach instead of a proactive. This theme is further revealed through the interviews, where most actors deal with the disruption when they occur, relying on flexibility, manual communication, and experience

to adapting plans and solutions such as rerouting and creating buffers. The reactive nature of resilience by the actors became evident when looking at how disruptions are handled. Such as manual adjustment, buffer time and stock or rerouting flows. As one of the interviewees noted, *"It's usually manual – someone must make a few calls and adjust the plan. It's not automated, but it works."* This mindset was also summarised by another interview as," We *are pretty good at handling problems when they occur."*

In handling disruptions, actors' ability to be resilient is based on personal networks and manual planning, however these strategies can be fragile, chiefly when volume increases. One interviewee stated that to handle these irregularities caused by disruptions, the company, *"Relies on experience to handle irregularities,"* and focuses the need for *"adjusting buffers depending on flow."*

As mentioned most actors had a reactive approach, but some of them are starting to research and develop a more proactive process. One actor stated internal initiatives to focus on resilience, while other interviewees also mentioned flexible inventory and use of different modes of transport. With this, a few limitations in the current approach were raised*, "We're not using all the information we have,"* suggesting that resilience work could be improved through better use of data and better systems such as predictive planning. Many respondents also highlighted the capacity constraints at the port, or a lack of a shared digital platform as challenge to increased and coordinated resilience. One actor explained while the port general flexibility works well, there is a need for the port to, *"handle increasing volumes from different customers"*. To summarize, the interviewed actors connected to the Port of Södertälje expressed their resilience strategies as manual, practical, and based on experience to navigate disruptions, instead of formalized plans and system solutions. This strategy, or rather approach has been sufficient in most scenarios up till this point, however this reactive model may not be enough for the future, and the respondents showed a clear awareness of the necessary move to more proactive, collaborative and data driven solutions.

4.2.5 Digitalization and ITS

Digitalization and ITS are integral parts of our study and therefore also our interviews. The level of engagement into this varied between the different actors, but there was a shared opinion that digitalization is significant and has major potential in improving coordination, resilience and operational efficiency. However, simultaneously there was challenges and limitations raised by the actors in their relation to the Port of Södertälje. As mentioned above in "Information Flow", the current communications between external actors and the port are seen and described as manual and basic. Some of the challenges that exists because of this is lack of a system or platform that shares data real time and in an accessible way. As one

respondent put it *“We don’t need anything fancy, just something that lets everyone see the same thing at the same time.”*

These challenges of non-existing systems, and a lacking information sharing were seen as important areas, but one actor has recently integrated their system with the TOS of the port to address these challenges. This interviewee answered, *”Yeah, we have integrated with API […] we have the same supplier of terminal operating system”* and, *“Yes, it saves everyone a lot of time […] It’s a lot better than what it was before we got it running.”* The interviewee continues to describe the significant improvement that had been achieved thanks to this integration of systems. The updated digital solutions now make information shows up in both systems directly. This has led to better communication and more data being accessible, saving time and creating a more efficient operation. When asked about room for improvement with digital solutions the focus was on automated handling of damages, to optimize the process, and limit the discussion who is responsible for the damage, leading to saved time and costs. Importantly, it was also mentioned that this respondent saw system failure, as the biggest possible disruption, e.g. by internet being down or the system crashing. This highlights the potential challenges with relying more on integrated digital systems.

There were other digital solutions that were brought up in the interviews. One respondent expressed that the general digitalization level is low in shipping companies and ports, *“I don’t think the digitalisation is enough, and the information flow from shipping companies and ports is generally slow.”* The respondent highlighted that the more information sharing, and the more connected systems and platforms the better. Highlighting increased use of technology that increases information, such as barcodes, tracking and GPS, suggesting that it would greatly increase the efficiency of their company’s operations.

As we can see there is potential improvements to made when it comes to digitalisation and ITS system to improve information flow, resilience and operational efficiency, and in the case of the TOS integration with the help of API, this has already been implemented and with major success. However, even though there is consensus that improvements can be made through digitalization solutions, there are still major challenges and drawbacks to implementing these types of solutions, and these are the once stopping more actors increasing their digitalization. There were three main challenges that came up in the interviews, and these are cost, complexity and return on investment (ROI). The clear biggest obstacle to increased digitalisation and ITS solutions for all actors is the cost associated with the necessary investments. One respondent noted that, *“it’s costly and complicated to implement new technology”* and another, *“And that’s how it is, it costs a lot of money. That is an obstacle, and it’s pretty hard to measure if it’s worth it from a cost perspective.”* These showcases that the

cost is a major factor in considering increased digitalisation. They also highlight the complexity, meaning specifically the complexity of either going from pen and paper to a digital system, or integrating 2 different digital systems. The second quote backs up the challenge of measuring the return of investment. All of these three, build on each other to create a general opinion of the respondents that these investments are costly, complex and hard to implement and by this also leads to uncertainty on return on investment (ROI).

Digitalization is seen as an important enabler to reach improved port collaboration and logistics, and to create a better information flow between the actors in the ecosystem and supply chain. Its potential to increase resilience and mitigate disruptions was also shared among most interviewees, however this aspect was varied in terms of how it was perceived, mostly in long term and short-term perspective, as well as how important a move from reactive strategy to a proactive strategy was to achieve this.

4.3 Survey Findings

To support the empirical investigation of digitalization in the Port of Södertälje operations, a structured online survey was conducted. The survey aimed to capture the stakeholders' perceptions regarding potential benefits, risks and future developments associated with increased digitalization within the port and logistics sectors.

Initially, respondents were asked to rate the likelihood of digitalization improving various aspects of ports and logistics operation within the next 5-10 years. Table 4.1. Summarize the results.

Table 4. 2

Area	*Mean Rating*
Improved communication between actors	3.67
Increased efficiency in logistic flows	4.33
Better handling of disruptions	3.83
Increased resilience (resistance to disturbances)	3.33
Reduced risk of information errors	3.67

Note: Expected Improvements Through Digitalization.

The results indicate on a high level of optimism among respondents. Increased efficiency in logistics flows was rated particularly highly, while increase resilience was rated the least strongly. These results show that while respondents generally expect digital tools to benefit logistics operations, particularly in terms of efficiency and coordination, expectations are more tempered when it comes to broader systemic outcomes such as resilience.

Further, the participants were asked to assess how serious they perceived different risks to increase digitalization as seen in table 4.2.

Table 4. 3

Risk	*Mean Rating*
Cyberattacks or IT intrusions	3.66
System failures or technology dependence	3.33
Lack of coordination between actors	1.66
Lack of competence in digital tools	2.66
Increased complexity creating new vulnerabilities	3.17

Note: Perceived Risks Associated with Digitalization.

Cybersecurity threats emerged as the most serious concern with a mean rating of 3.66. Additionally, system failures and increased complexity were viewed as notable risk, whereas a lack of coordination and competence were perceived less as critical by most respondents.

Following, the respondents were asked about the likelihood of various developments occurring with the next five years. The participants responses indicated moderate to high expectations of partial digital transformation.

Table 4. 4

Trend	*Mean Rating*
Digitalization increases but implementation is uneven	3.67
Manual processes continue alongside digital ones	3.67
Willingness to digitalize exists but resources are lacking	4

Note: Anticipated Future Trends.

The results indicates that respondents expect digitalization to progress but not uniformly. At the same time, manual and digital systems are likely to coexist. While there is a desire to digitalize, resource constraints could hinder development. These include economic limitations, such as high investment costs and uncertainty around return on investment, as well as technical challenges, including system integration issues and lack of standardized platforms.

Furthermore, the participants were asked which three future scenarios they considered most likely. In the best-case scenario, full digitalization is achieved alongside strong inter-

organizational collaboration, resulting in highly efficient, resilient, and integrated port operations. In contrast, the worst-case scenario describes limited progress in digital adoption, continued fragmentation among actors, and a failure to adapt to evolving regulatory and operational demands. The moderate-case scenario, selected by all respondents, envisions partial digitalization with uneven implementation across actors. In this scenario, some progress is made in areas such as information sharing or operational tools, but legacy systems and coordination gaps persist, preventing full systemic integration.

As shown in Table 4.4, all respondents selected “Moderate case”. No respondents believed in any of the more radical alternatives, which suggests a generally cautious but optimistic outlook. Instead, 100% of participants selected the moderate-case scenario as the most likely future development.

Table 4. 5

Scenario	*Percentage of respondents*
Moderate Case: Partial digitalization and some collaboration	100%
Best Case: Full digitalization and strong collaboration	0%
Worst Case: Limited progress, fragmentation	0%

Note: *Most likely future scenario.*

Lastly, the respondents identified areas which they believed should be prioritised to achieve a positive future in terms of a port ecosystem that is more efficient, adaptive to disruptions, and aligned with emerging digital standards. Table 4.5 reveals the distribution of responses.

Table 4. 6

Priority Area	*Number of Selections*
Information flow and data sharing	4
External collaboration with actors	3
Investment in technologies/infrastructure	3
Internal coordination within the port	2
Competence and education	2
Security and cybersecurity	2
Emergency preparedness and back-up solutions	2
Policy framework and regulation	0

Note*: Priority areas for positive development*.

Improving information flows, foster external collaboration, and investment in technologies and infrastructure were the most frequently mentioned priorities. It indicates that communication and cooperation are key enablers of a successful digital transformation.

5. Discussion

This chapter interprets the empirical findings in relation to the research questions and relevant literature. It highlights interesting findings, key themes, compares stakeholder perspectives, and explores possible future scenarios for digitalization and resilience in Swedish SMSPs.

5.1 Key Themes

This section presents the key themes that emerged from the data collection. The analysis is structured around four interrelated dimensions: digitalization and ITS implementation, information flow and interorganizational collaboration, resilience and response to disruptions and the public vs. private perspectives.

5.1.1 Digitalization and ITS Implementation

The theme of digitalization and ITS implementation reflects on the fragmented and underdeveloped state of digital infrastructure and practices in the Port of Södertälje. This aligns with the evidence across small and medium-sized ports (SMSPs) in Sweden. The findings in table 4.1 show that most ports have adopted tools such as Terminal Operating Systems (TOS), and automated gate systems. However, full integration into a cohesive digital infrastructure remains limited. Only a subset of ports has begun to implement predictive tools or Port Community Systems (PCS) that support real-time collaboration and resilience. Although, ports such as Helsingborg and Norrköping demonstrate broader implementation across multiple domains, indicating a relatively higher level of digital maturity. Further, the data also reveals that digitalization remains uneven across SMSPs. Smaller ports, such as Piteå and Mälarhamnar, show limited initiatives, often confined to a single system or function.

The interview data revealed issues such as low platform integration, reliance on manual communication channels such as emails and telephone, and the absence of a comprehensive IT strategy. The participants highlighted that there is a lack of digital systems capable of supporting information flow, and predictive planning. These are factors that are increasingly important in the contemporary supply chain faced with diverse volatility. There exists both potential for beneficial solutions as well as major challenges for an increased digital maturity. Stakeholders are not seeking super high-tech solutions or systems, but emphasis a vision of predictive arrival systems, automated damage management systems, shared dashboard and real-time visibility. Stakeholders understood the main challenges for these solutions as high costs, complex integration and standardization, as well as hard to measure the benefit. With this base, the consensus was that there is a big upside to investing in basic digital systems and infrastructure, to improve information flow, collaboration, operational efficiency and

resilience. Evidence could be found in how other SMSPs integrate Port Community Systems (PCS) or Time Slot systems for arrivals of trucks and vessels.

From a theoretical standpoint, the former aligns with the literature on digital transformation and digital maturity (Kane et al., 2015; Lind et al., 2021). As described in the literature review, digitally mature organizations demonstrate the ability to embed digital technologies not only as isolated tools but an integral part of strategic, operational, and cultural practice. However, the Port of Södertälje, like many SMSPs, is engaged in what Raza et al., (2023) express as the "digital divide" where structural barriers such as limited financial resources, outdated infrastructure, and fragmented organizational cultures prevent achieving digital maturity.

The transformative potential of Intelligent Transport Systems (ITS) including tools such as predictive analytics, automated data capture, and an integrated scheduling platforms have been evident in research (Ivanov & Dolgui, 2021; Parola et al., 2021). However, the findings indicate that such systems are currently absent or underutilized. This is consistent with Kane et al. (2018), and the ports level of digital maturity is not only in a technological context but also cultural. The strategies are fragmented and here is no real push by leadership for more digital integration. This could explain the interviews references to the somewhat informal workarounds and sometimes delay in coordination. If there is no strategic vision in the leadership for digital adaptation, it will most likely keep being siloed rather than a clear systematic strategy approach. The lack of ITS adoption limits operational efficiency and compromises the ports ability to anticipate and respond to disruptions, which is evident in the resilience literature (Fan & Stevenson, 2018).

While the findings met some expectations set by earlier research (Lind et al., 2021; Almeida, 2023) of SMSPs that they often lag in digital maturity because of a lack of resources. In some areas there were unexpected results, such as that the respondents showcased a high satisfaction even though the digitalization level was low. There is more than just a technical shift to increased digital maturity and digitalization level, the organizational culture and cultural environment play an important role. To further understand this results, a point of view could be that the Port of Södertälje current volume relevant to the interviewed actors and the operational complexity of this relatively small port is not high enough to create a pressing need for change, and that old practices have created a level of control deemed satisfactory.

Overall, the themes support the assertion in the study that digitalization is not an optional enhancement but a fundamental enabler of resilience and competitive viability in the port sector. Without the implementation of coherent and integrated digital systems the port might be increasingly vulnerable to both expected and unforeseen disruptions.

5.1.2 Information Flow and Interorganizational Collaboration

The theme of information flow and interorganizational collaboration highlights the current state of communication and collaboration between actors in and around the Port of Södertälje. The interviews expose a dependency on informal and traditional communication methods such as telephone calls, email and face-to-face interaction rather than structured and interoperable digital platforms. At the same time, these relational and proximal forms of communication were often described as effective and practical in the short term. However, there is a systematic lack of integration that could pose a significant challenge for transparency, accountability, and crisis response. Additionally, table 4.1 show that digital initiatives supporting interorganizational communication are less widespread overall. Only a few ports have implemented tools such as Port Community Systems (PCS), Electronic Data Interchange (EDI), or shared dashboards. This limited integration hinders real-time data sharing and coordinated planning across stakeholders.

The former aligns with the literature on organizational information flows and platform-based integration, which states that a lack of integration and standardization are key barriers to effective intermodal and multimodal logistics (Gerlitz & Meyer, 2021; Lind et al., 2021). The Port Community System (PCS) model was discussed in the study as a benchmark to enable seamless data sharing among port stakeholders (Notteboom et al., 2022). However, the findings reveal that current practices in the Port of Södertälje are in sharp contrast to that. Without such systems, the coordination between shipper, terminal operations, logistics providers and inland transport remains fragmented and vulnerable to miscommunication or delayed reaction.

The sub-themes within this broader category being “Stakeholder Accessibility” and “De-centralized Data Handling”. It further reflects the lack of systematic visibility. Meaning, that it can significantly inhibit anticipatory logistics and synchronized planning. As some interviewees mentioned, it is not uncommon for key information about cargo arrivals or booking changes to be delayed or routed through multiple intermediaries. These findings reinforce the concern evident in the literature expressing that fragmented communication ecosystems heightens operational inefficiencies and slow down response times during disruptions (Karlsson et al., 2024; Polemi, 2018).

Overall, the themes describe a critical tension in the port’s resilience framework. While interpersonal relationships alleviate the lack of digital coordination systems, the workaround is inherently unsustainable. Especially, if the port strives to scale up volumes of the goods handled in their operations. Therefore, it underlines the need for standardized, interoperable

and real-time communication infrastructure that supports not only routine operations but also adaptive responses to disruptions.

5.1.3 Resilience and Response to Disruptions

The theme of resilience and response to disruptions encapsulate how actors in the Port of Södertälje experience, perceive, and manage disruptions ranging from weather related events and equipment breakdowns to communication failures and labour shortages. The disturbances caused by weather can be categorized as natural disruptions, labour shortages and communication failures as human made disruptions, and equipment breakdowns as system accidents (Ali et al., 2021). The PESTEL framework (International Association of Ports and Harbors, 2023) can be used to interpreted the mentioned disruptions and vulnerabilities. This highlights how political, economic, social, technological, environmental and legal factors affect and shape port operations. Social dynamics such as labor shortages and communication inefficiencies. As well as political and legal dynamics such as the TEN-T initiative as part of the PESTEL lens puts an emphasis on the operational vulnerabilities that exists in the Port of Södertälje and shows how not only internal issues, but also external issues shape the port system.

Firstly, digital tools specifically aimed at enhancing resilience are limited across SMSPs. Table 4.1 indicates on a stronger focus on technologies addressing system-related and human-made disruptions such as TOS, smart sensors, and automated gates. Rather than predictive or adaptive systems. Initiatives targeting natural or financial disruptions, like climate monitoring or digital payment platforms, are rare. This indicates that resilience is not yet a primary driver of digitalization strategies in most SMSPs. The focus remains on improving daily operations rather than building long-term adaptive capacity.

The interviews revealed that the Port of Södertälje has adapted through operational experience and improvised flexibility. However, it lacks a formalized strategy or digital architecture for resilience. Except that the port authorities believe that in case of severe disruptions, a manual handling of their operations should be possible. At the same time, several references were directed to unpredictable arrivals, delayed responsiveness, and infrastructural limitations. It signifies that resilience is being pursued reactively rather than proactively.

In the literature, resilience is conceptualized through the dimensions of readiness, response and recovery (Chowdhury & Quaddus, 2016; Christopher & Peck, 2004). The findings suggests that the port is strongest in the “response” phase, particularly due to the close interpersonal networks among operators. However, the port is weaker in “readiness” as there is a lack of scenario planning or predictive modelling, among other factors. Further, the port is

only modesty engaged in “recovery”, for instance post disruption learning or system adaptation. This aligns with the work of Fan & Stevenson (2018) which states that many port systems prioritize risk mitigation over resilience building. Thereby neglecting opportunities for transformation and long-term improvement.

The findings are varied regarding the literature on the role of digital technologies in enhancing resilience. For instance, ITS tools such as predictive maintenance systems, real-time monitoring, and automated exception handling are described as sometime essential or with great potential to modern ports resilience, especially the larger ones (Ivanov & Dolgui, 2021; Y. Yang et al., 2018). However, the interview data indicates that such tools are not actualized in the Port of Södertälje. Therefore, the port remains vulnerable to disruptions not because such tools are ineffective but because they are absent or insufficiently integrated.

Furthermore, the findings illustrates how financial and systematic disruptions are visibly in this theme (Ali et al., 2021). It is evident that there exists reactive, and labour-intensive coping strategies in a context of logistical complexity and environmental uncertainty. Since ports like Södertälje face pressure from the TEN-T digitalization mandate, the lack of preparedness and the absence of real-time coordination tools become more than operational issues and rather a strategic liability.

An unexpected result was how disruptions were viewed by the stakeholders. Disruptions are a normal part of operations, and not a major challenge to consider in their operations. Taking a more reactive approach when dealing with them and not stressing them as important operational challenges. This might be explained by the fact that respondent’s interviewed was mostly closely located to The Port of Södertälje, and operating mostly in a Swedish context. This could mean that supply chain challenges and disruptions of port activities are not so vast when compared to a more global context. It could also be explained in part that the port of Södertälje is very well located, as an inland port it is well protected from weather related disruptions and have a strong foundational resilience to natural disruptions because of its geographic location and properties.

The analysis shows that The Port of Södertälje resilience mechanisms is of an ad-hoc nature and this can be further understood through the IAPH risk and Resilience Framework. Organizational, access, and technological risk is impacting the port as show by the references to labour shortages, outdated or non-existent systems as well as the sometimes-existing bottlenecks. Continuing through the lens of the IAPH, the Port of Södertälje exists primarily as a platform of logistics, and its resilience measures are mostly managed locally and operational.

5.1.4 Public vs. Private Perspectives

There is a distinction to me made in this research, showing the contrast between public and private dimensions. Existing research tends to focus on the role of port authorities in making digital change, however this study instead focuses on the private actors, such as manufacturers, forwards, and logistic companies. This gives a niche approach which furthers insight into how resilient port operations are perceived from an outside and private perspective, and what these customers and users think and expect when it comes to digitalisation. Through combining the private perspective (RQ2) and the public perspective (RQ1), this study bridges the gap between digital governance and the lived experience of industry professionals in Swedish SMSPS.

The interview findings show how the private side of port activities views digitalization, information flow, disruptions and resilience. Comparing this to the digitalization initiatives in other ports made by port authorities, hence, the public side shows how there exist different priorities. Digitalization initiatives in Swedish SMSPs are overall project specific and digital tools such as RFID access, environmental monitoring sensors and automated gate systems are seen in multiple locations, but there is uncertainty to what extent this system are integrated in the port operations, and how they are used and shared with private external actors. The available data gathered does not clearly indicate the level of integration between actors and within the digital framework. However, it is clear that the port authorities in Swedish SMSPs have digital systems and initiatives that focuses on addressing natural disruptions (CO2 reduction, IoT environmental monitoring, smart energy), human-made disruptions (Automated gate control, RFID, automation) and system disruptions (TOS, AI pilots, camera/sensors).

A comparative analysis of the findings related to the different research questions reveals a significant tension within the digitalization landscape of Swedish SMSPs. Namely, a misalignment between public-sector digital initiatives and private-sector digital experiences. On one hand, the public actors have initiated and implemented various digitalization systems and solutions aimed at enhancing operational efficiency and resilience. These include systems for traffic coordination, berth allocation and environmental monitoring which are often supported by government-funded programs or regulatory mandates.

On the other hand, insight evident in the findings from the private sector actors, reveals a contrasting perspective. Many of the actor's report on challenges related to fragmented information flow, limited systems interconnectivity, and restricted access to real-time data. Despite the presence of digital infrastructure initiated by port authorities, private actors experience the port environment as siloed with insufficient integration between in-house systems and public digital platforms.

5.2 Best-Moderate-Worst Scenarios

To complement the empirical findings, a scenario-based methodology was applied to explore possible future trajectories of digitalization and resilience in the Port of Södertälje. The three scenarios, namely, best-case, moderate case, and worst case, are analytical tools that combine observed trends, strategic uncertainty, and stakeholder expectations. The scenarios are not predictive. Instead, the scenarios are organized based on the interviews and the survey data, to illustrate the effects of differing degrees of digital adoption, integration and cooperation.

5.2.1 Best Case

In the best-case scenario, the Port of Södertälje will successfully transform into a fully integrated and resilient logistics hub. It would be characterized by advanced digitalization, seamless collaboration among stakeholders, and strong environmental performance. By 2030, the port has strategically implemented a comprehensive array of Intelligent Transport Systems (ITS) such as sensor to monitor air and water quality, noise and emissions, and a port community system (PCS) that connects all port stakeholders. It would overcome the previous fragmented state across all Swedish small and medium-sized ports (Lind et al., 2021). Operational processes at the port have become synchronized with hinterland connection, addressing critical gap found in the survey. This includes real-time tracking of vessels, cargo, and intermodal flows which enables optimized scheduling, minimizes delays and enhances services reliability.

The digital infrastructure now in place has been supported by collaborative investments between port authority, shipping lines, terminal operators and inland logistics providers. The greats operational proactive improvement has been derived from better information exchange and data transparency which facilities better responses to disruptions. Predictive analytics tools have been developed within the terminal operating system to allow the port to forecast cargo peaks and potential bottlenecks. Further, there has been put an emphasis on flexible infrastructure and strong communication networks which have been facilitated trough digital platforms that integrate customs clearance, security checks and cargo inspections.

Moreover, the Green Goods Hub project has now been finalized. Alongside the environmental benefits stemming from the project, the port now offers multimodal options prioritizing rail transport, hybrid trucking and electrified last-mile solutions. Renewable energy sources, including solar panels, supports the ports operations. The environmental metrics are monitored digitally in real-time ensuring compliance with the uncompromising sustainability regulation put in place by the European Union. This transition has made the Port and attractive logistics hub, particularly for industries such as pharmaceuticals, automotive, and food logistics where both resilience and compensatory green credentials are important for their competitive edge.

The resilience of the Port of Södertälje has operationalized through the dimension's readiness, responses and recovery defined by Christopher and Peck (2004). It includes partaking in regular crisis simulation exercises, informed by predictive digital models which ensures organizational flexibility when disruptions occur. Through establishing alternative plans between maritime and hinterland actions, disruptions such as labour strikes, cyber incidents, and extreme weather can be absorbed with minimal downtime in operations. The data collected within the terminal operating systems can be used to facilitate a digital twin which enables the port to conduct simulations of disruptions, change of operations or potential investments.

At the same time, the cultural shift within the port eco-system is significant. The strong local relationships have remained important. Although, digital trust building through EDI, and blockchain verified-cargo transactions have strengthen the partnerships. There now exists standardized strategies to enable seamless communication with all new customers willing to use the port in their supply chain. The low IT integration maturity in Swedish small and medium-sized ports have therefore been addressed, and it positions the port as a leader among the others and provides a benchmark for digital resilience in logistics.

Overall, the port of Södertälje exemplifies how overcoming institutional fragmentation, investing in interoperable technologies, and fostering a shared vision of sustainability can lead to a digital mature, resilient and environmentally responsible port.

5.2.2 Moderate Case

In the moderate-case scenario, the Port of Södertälje has made significant progression in its digitalization journey. However, progress remains uneven and fragmented. While improvements have been achieved compared to contemporary levels, structural barrier persists that prevent the port to realizing becoming a digital resilient logistics hub. As revealed by the interviews and the survey, the port initiatives to integrate Intelligent Transport Systems (ITS) and establish a functional Port Community System (PCS) is only partially successful. Endeavours have been made to integrated actors through APIs, but interoperability among stakeholders remains limited. This cause delays, miscommunications and redundancies.

Digitalization efforts have largely focused on individual operational areas rather than a coherent strategy across the port domain. For example, shipping schedules can be managed through an improved integrated Terminal Operating System (TOS), but other operational areas such as transport coordination and customs procedures remain a manual process. The findings indicated that such fragmentation is much an issue as in other Swedish small and medium-sized ports (Lind et al., 2021). While the adoption of real-time tracking for vessels and

basic cargo operations has reduced minor disruptions, the critical gaps in system integration undermined the ability of the port to respond with agility facing severe disruptions.

Interview participants highlighted that communication among stakeholder has improved compared to prior years. These operational updates are exchanged through email, telephone and isolated digital tools. Therefore, the absences of a centralized data-sharing platform limit the ports' ability to optimize functions such as berth management, hinterland logistics and disturbance response coordination. In line with the work on environmental initiatives it has gained visibility. Functions such as shore power stemming from the Green Goods Hub project has made progress, but there has been a limited increase in rail transport share and only plans for electric vehicles charging stations.

From a resilience perspective, the port has enhanced its capacity to absorb moderate disturbances such as supply chain bottlenecks or temporary labour shortages. However, larger disruptions including cybersecurity threats and economic slowdowns continues to be significant risks. While some contingency plans exist, it is inconsistently applied across different operational actors at the port. Thus, it reflects on the absence of a unified resilience framework as explained by Christopher and Peck (2004).

Stakeholder collaboration has become more strategic. Similarly, trust between organizations has improved marginally through operational meetings and informal networks, but the lack of formal digital trust mechanisms such as PCS, or blockchain-based cargo verification hinders the development of a fully integrated port ecosystem. The interviewees frequent emphasis on the importance of face-to-face relationships suggests that cultural barriers to full digitalization will remain a challenge within the port community, if the port do not take initiative.

Overall, the Port of Södertälje has achieved partial digital maturity by 2030. Although, shortcomings remain in the system integration, resilience building and environmental sustainability. While the port manages to operate more efficiently, it continues to be vulnerable to disruptions. Without a stronger commitment to integrated digital strategies and stakeholder collaboration, the port risks to be outmanoeuvred by more advanced ports in the region.

5.2.3 Worst case

In the worst-case scenario, the Port of Södertälje has failed to undertake the digital transformation necessary to maintain operational resilience and competitiveness. Despite early recognition of the for digitalization, both stakeholder interviews and survey results reveal a continuous lack of coordination, investment and strategic focus. The digitalization has remained fragmented and superficial, limited to isolated upgrades in the collaboration with individual organization. While there is a complete lack of a coherent, standardized port-wide

system. The Port of Södertälje exemplifies the stagnation and struggle with outdated infrastructure and financial constraint as described by Lind et al., (2021). The attempts to implement Intelligent Transport Systems (ITS) ad a Port Community System (PCS) have been abandoned, or resources has not been found. This results in the continued reliance on manual operations, emails, and telephone calls for critical communication.

The consequences of these shortcomings are significant. The port fails to capture the increasing demand for sea shipping, while the coordination of goods suffer from delays, lost and damaged goods information, and inefficient resources use. The interviews with stakeholders highlighted ongoing problems with real-time visibility across the supply chain, a challenge that has only worsened due to the ports failure to implement interoperable digital platforms. Without the integrated systems, the port continuous to remain vulnerable to both predictable and unexpected disruptions. Severe weather events, cybersecurity breaches, and labour inefficiencies cause prolonged operational shutdowns. Therefore, exposing the fragile infrastructure and limited crisis management capacity. Resilience, as defined by Christoper and Peck (2004) through readiness, response and recovery capabilities remains critically underdeveloped.

Stakeholder collaboration will remain stagnant, as frustration mounts between shipping lines, port authorities and inland carriers. The trust between the stakeholders erodes due to misaligned priorities and outdated communication practices. This can result in conflicting schedules and costly misunderstandings due to the port overachieving in the act of taking in more customers without the proper infrastructure. The cultural resistance found evident in the interviews and survey is solidified by outdated practices that hinder necessary modernization. Without shared digital platforms or transparent governance structures, the operational silos dominate the port environment and undermines any collective strategic efforts.

Similarly, environmental initiatives suffer. The investments stemming from the Green Goods Hub has been made but with intangible progress in other areas. The intermodal transport integration is weak and the reliance on road freight remains high. The investments in renewable energy infrastructure, and charging stations are neglected. The port fails to meet the target framed by the TEN-T framework, and that results in reputational damage and loss of resources. The survey highlighted the need for increased importance of green logistics among stakeholders, which the port is unable to capitalize on.

In the future, the ports relevance in the regional logistics network diminishes. The competing ports in the Stockholm-Mälaren region, have successfully implemented integrated digital and green strategies which attracts the shipping volumes that the Port of Södertälje once imagined for themselves. The port becomes marginalised, serving only low-margin and infrequent cargo

flows. The broader economic impact for the region results in job losses, declining investments and reduced industries.

Ultimately, the worst-case scenario highlights the severe consequences of not addressing the systematic digitalization and collaboration challenges. Without strategic foresight and resilient infrastructure, the port continues to be an example of how small and medium-sized ports risk obsolescence in a competitive and digitally driven logistics sector.

6. Conclusion

This chapter summarizes the main findings of the study, reflects on their implications, and outlines the study's contributions, limitations, and recommendations for future research and practice.

6.1 Key findings

The study explored the implementation and impact of digitalization initiatives, specifically Intelligent Transport Systems (ITS). Set within the context of Small and medium-sized ports (SMSPs) with a particularly focus on the Port of Södertälje. Moreover, the purpose of this research was to understand the problem that small and medium-sized ports (SMSPs) face as critical logistics hubs, when adapting to digitalization. The clear challenge and distinction in this research are that larger ports have higher digital maturity, and SMSPs often function with smaller financial resources, less developed infrastructure and fragmented digital systems and information flow. Due to the lack of digital tools, low integration in inter-organizational collaboration, and a lacking real-time information sharing it threatens their ability to respond efficiently to disruptions and hampers their development of their long-term resilience. SMSPs may struggle to effectively incorporate digitalization to enhance their operational efficiency, management of disruption, stakeholder coordination and information flow.

It was guided by two central research questions addressing practical deployment of ITS and the influence on information flow and port resilience. Following, the two research questions are presented:

RQ1: "How are digitalization initiatives (ITS) being implemented in Swedish small and medium-sized ports (SMSPs) to enhance operational efficiency and resilience, particularly during disruptive events?"

RQ2: "How does digitalization (ITS) improve information flow among port actors, and how does this contribute to strengthening resilience in the Port of Södertälje?"

In response to RQ1, the findings demonstrates that SMSPs in Sweden are increasingly integrating digitalization strategies. However, there is a varying level of sophistication. The adoption of digitalization tools has predominantly been driven by the integration of an advanced Terminal Operating System (TOS). Although, the initiatives implemented are primarily focused on system-related and human-made disruptions, through improvement of monitoring real-time, access control and coordination. Additionally, there are targeted measures addressing specific risks, such as Internet of Things (IoT) pilots, smart sensors and other tools such as artificial intelligence (AI).

Digitalization in Swedish SMSPs is driven by a combination of factors, including regulatory requirement such as the TEN-T framework, local operational needs, growing awareness of the importance of resilience, and a focus on efficiency and sustainability, particularly in areas like energy management. Findings suggest that increased resilience is emerging, however, the governance and integration of digitalization is still underdeveloped and does not reach its full potential.

In response to RQ2, the case study of the Port of Södertälje highlights how digitalization can enhance the flow of information across port actors. Especially, for terminal operators and shipping lines. The digital integration of stakeholders through platforms enabling real-time data sharing can reduce information asymmetries, improved coordination and minimized delays. These improvements in informational connectivity can in turn enhance the ports resilience by enhancing its capacity to anticipate, absorb and recover from disruptions. However, the current information flow relies on manual communication methods, and function under stable conditions, although they are insufficient for handling disruptions effectively. Through implementation of more advanced and standardized digitalization tools, the port could enable more synchronized decision making, faster information exchange, and an earlier identification of potential challenges. These tools would improve operational resilience through a change from reactive to proactive strategy, reducing the dependability on individual experience. Through digitalization, the port would be better at absorbing and recovering from disruptions, while at the same time improving collaboration and creating a more efficient supply chain.

Although, disruptions are manageable and a normal part of operations, with a reactive approach to dealing with them. But there is a systematic problem, of limited space and volume flexibility, as well as limited real time information causing negative effects on the supply chain, the ports and its adjacent operations. Disruptions of key importance for the actors were in terms of human made disruptions such as labor shortages and communication failures, as well as system accidents such as equipment breakdowns and damages. The resilience to deal with disruptions is strongly based on adaptability, flexibility, experience and manual coordination and solutions. Some resilience strategies were noted, such as buffer stock or rerouting of goods and the use of different modes of transport. But generally, there is no structured digital resilience strategy in place, and the solutions are created in a reactive manner.

At the same time, the case study on the Port of Södertälje illustrates broader patterns around the first research question. As a representative of SMSPs, the port examples challenges and strategies observed across the industry. The ports implementation of digitalization initiatives was shaped by its unique operational context and resource constraints. The lack of

interoperability and standardization hampers the adoption of digitalization and creates vendor-specific solutions. Therefore, it limits scalability and knowledge of transfer across the sectors. It sheds light on the systematics fragmentation in digital infrastructure that exists within SMSPs in Sweden. Moreover, the digital maturity of the collaboration and processes between the Port of Södertälje and surrounding actors is lower than the digital maturity of the external actors themselves. Many of the stakeholders saw that their own internal digitalization is higher when compared to the processes and collaboration with the port. With this, there also exists a mismatch as the internal systems are integrated within the company itself while systems are not connected to the port operations. However, most actors did not see this as a major problem, mostly seeking basic digital solutions at the port. However, there was a positive outlook on whether improvements can be made and that it would be beneficial for their collaboration and the port itself.

Further, the asymmetry between public and private digital capabilities and experiences highlights a broader systematic issue within the port ecosystem. It indicates that digitalization is progressing but is doing so unevenly and in ways that do not always translate into tangible improvements for all stakeholders. The lack of common standards, limited interoperability, and minimal co-development of digital solutions contribute to a fragmented ecosystem in which the full potential of digitalization and intelligent transport systems to enhance resilience and efficiency are underutilized.

6.2 Implications

The findings are relevant for both academia as well as practice for industry professionals working with management of SMSPs, particularly in Sweden. For practice, the research shows an important and achievable need for increased implementation of digital systems. The Port of Södertälje can enhance their operational efficiency without the need for massive technological and system overhauls. Not increasing the digital maturity of SMSPs can make ports fall behind and lose their attractiveness, especially as supply chains become increasingly more digitally integrated, largely owing to frameworks such as EUs TEN-T framework demanding increasingly higher standards for digitalization and sustainability. For academia, this study might bring insight into hidden vulnerabilities in SMSPs. For instance, stability in operations is achieved in the current state. However, it could lag in dealing with future risks, by falling behind in development in comparison to bigger ports and not bridging the gap in digitalization. A way to achieve this bridge of the gap is not only through digital and technical solutions but as well as better stakeholder integration and standardization across networks, digital tools and platforms.

6.3 Limitations

While we deem this research to be a valuable contribution, it has faced some limitations. Firstly, since this is a single case study the findings are specific to this context and cannot directly be completely generalized to all SMSPs with our caution. The Port of Södertälje shares characteristics with other SMSPs. However organizational and regional variations must be considered to fully understand the extent of the findings. Secondly, as a consequence of restrictions in security and limited access to specific details of internal data form the port, as well as of technical and digital infrastructure, the research faces challenges in the evaluation of digital systems and resilience measures leading to a lack of depth in understanding and findings. However, even with these limitations the findings are credible and valid in understanding key challenges, opportunities and patterns facing SMSPs navigating digitalization in a context of resilience and information sharing.

6.4 Recommendations for Future Research

There are many potential ways to approach future research, what we suggest as the most important is to conduct a multi-case study across many SMSPs. By doing this the research would be broader and be able to better identify and understand patterns at The Port of Södertälje and across other region such as on a national level in Sweden or regional level of Europe etc. Further, it would be beneficial to conduct future research with quantitative methods to better understand KPIs, and how different digitalization efforts align and affect them. Researching from a cultural and organizational perspective, as well as a policy perspective could bring important angels. Lastly, a more detailed and focused effort to weigh different systems and their cost, to truly understand the cost and ROI challenge would greatly benefit this research, mostly for the ports themselves. Below follows recommendations for practical implementation of digital solutions for The Port of Södertälje the study has found to be the most pressing and most beneficial to implement.

6.5 Practical Recommendations

Based on the findings of this study, it is recommended that the Port of Södertälje prioritizes the implementation of a shared digital platform to improve information flow and transparency among stakeholders. With these, actors could access synchronized, real-time data for port operations and cargo status. Such systems being able to mitigate human-made disruptions like labor strikes and congestion by improving communication and operational efficiency. Integrating predictive scheduling and congestion management tools within the existing Terminal Operating System (TOS) would also enhance planning and resilience. Further, standardizing the integration of TOS with other actors would improve flexibility and planning

capabilities and can minimize the breakdown of operations and equipment through data monitoring and early warning detection. Having in-house expertise in this field would be highly valuable. Furthermore, introducing a simplified Port Community System (PCS) could enable secure and standardized data exchange across organizational boundaries. This system could handle secure data change between the port authority, shipping companies, transport operations and other industry customers and actors. A PCS platform can help mitigate human made and financial disruptions through improved transparency and cooperation. These measures, although modest in technical ambition, are aligned with the port's current operational scale and constraints and represent a strategic step toward enhancing digital maturity and port resilience.

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8. Appendix A – Interview Questions

1. Background
a. Can you tell me about your position and your experience working at (company)?
b. Do you have any experience with digitalization, and if so, what kind?

2. The Port
a. Can you describe how your collaboration with the Port of Södertälje works?
b. What do your current processes with the Port of Södertälje look like?
c. In this collaboration and these processes, what do you consider the biggest challenge?
d. In this collaboration and these processes, what do you consider the biggest opportunity?

3. Information Flow
(How information is transferred or disseminated from one person, place, or system to another. This can occur through speech, writing, signals, or digital data. The goal is for the right information to reach the right recipient at the right time.)
a. How does the exchange of information between your company and the port currently function?
b. Do you perceive any deficiencies in the current information flow between you and the port?
c. What digital systems do you use to communicate or collaborate with the port?
d. In your view, how could the current information flow be improved?

4. Disruptions
(Refers to interruptions or problems that affect the normal flow of work in a supply chain. This could include delays, technical failures, strikes, weather conditions, security issues, or other factors that hinder loading, unloading, or transport of goods.)
a. When you think about disruptions that can affect your collaboration with the port, what do you see as most critical?
   i. How are such disruptions handled today, and what could be improved?
b. What types of disruptions do you find particularly challenging in your context?
   i. Natural disruptions
   ii. Technical disruptions
   iii. Human-related disruptions
   iv. Economic disruptions
c. What changes could be made to increase efficiency and reduce disruptions?

5. Resilience
(The ability to manage, adapt to, and recover from difficult situations, disruptions, or changes.)
a. What does resilience mean to you in relation to port operations?
b. How well do you think the Port of Södertälje handles and recovers from these disruptions?
c. What would you like the port to improve in its work on resilience against disruptions?

6. Digitalization (ITS)
(The use of digital technology and Intelligent Transport Systems (ITS) to improve efficiency, safety, and sustainability in transportation and logistics.)
a. How would you describe the current level of digitalization solutions in the port and in your collaboration?

i. Do you think it is sufficient?

b. Is there any system or solution you believe could improve the port's information flow or resilience to disruptions in your collaboration?

c. What opportunities and challenges do you see with increased digitalization?

7. Closing

a. Do you have any final comments or suggestions?

8. Appendix B – Survey questions

Question 1.

Hur sannolikt är det att digitalisering kommer att förbättra följande områden inom 5–10 år?
Skala: 1 = Inte alls sannolikt, 5 = Mycket sannolikt

	1	2	3	4	5
Förbättrad kommunikation mellan aktörer	○	○	○	○	○
Ökad effektivitet i logistiska flöden	○	○	○	○	○
Bättre hantering av störningar	○	○	○	○	○
Ökad motståndskraft (resiliens)	○	○	○	○	○
Minskade risker för informationsmissar	○	○	○	○	○

Question 2.

Hur allvarliga anser du följande risker vara kopplade till ökad digitalisering?
Skala: 1 = Inte allvarligt, 5 = Mycket allvarligt

	1	2	3	4	5
Cyberattacker eller IT-intrång	○	○	○	○	○
Systemfel eller teknikberoende	○	○	○	○	○
Bristande samordning mellan aktörer	○	○	○	○	○
Kompetensbrist inom digitala verktyg	○	○	○	○	○
Ökad komplexitet som skapar nya sårbarheter	○	○	○	○	○

Question 3.

Hur troligt är det att följande kommer att ske inom 5 år?

	1	2	3	4	5
Digitalisering ökar men är ojämnt implementerad	○	○	○	○	○
Manuell hantering används parallellt med digitalt	○	○	○	○	○
Det finns vilja att digitalisera, men resurser saknas	○	○	○	○	○

Question 4.

Vilket av följande framtidsscenarier anser du som mest sannolikt?

- ○ Best Case: Hög digital mognad, starkt samarbete, hög resiliens
- ○ Moderate Case: Delvis digitalisering, viss samverkan, kvarstående sårbarheter
- ○ Worst Case: Bristfällig digitalisering, låg samordning, höga risker vid störningar

Question 5.

Vilka av följande områden anser du är viktigast att prioritera för att nå en positiv framtid?

Välj upp till 3 alternativ:

- [ ] Informationsflöde och datadelning
- [ ] Säkerhet och cyberskydd
- [ ] Intern samordning i hamnen
- [ ] Externt samarbete med aktörer
- [ ] Investering i teknik/infrastruktur
- [ ] Kompetens och utbildning
- [ ] Krisberedskap och backup-lösningar
- [ ] Policyramverk och reglering