UiA University of Agder

The potential for Port 4.0 in a small Norwegian seaport

- A case study of the Port of Kristiansand's container terminal

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Preface

This master‘s thesis concludes the end of our academic journey and is a part of the master‘s program in Industrial Economics and Technology Management at the University of Agder. The scope of the master‘s thesis is 30 credit points (ECTS).

We extend our sincere thanks to the respondents from the port authorities at the Port of Kristiansand, Seafront, and former RedRock.AI for their participation. A special thank you to our contact person in the Port of Kristiansand, Christine Alveberg, for her engagement and cooperation. Additionally, we would like to thank our friends and family for showing us great support throughout the writing process.

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Abstract

The Port and Maritime industry has since the 2010s undergone a significant digital transformation and is facing new challenges such as increased pressure regarding productivity, sustainability, as well as security and safety risks. This has, among other things, led to the development of smart ports. However, the adoption of automation has taken place in a slower pace than comparable sectors. Moreover, the literature related to smart port development in Norway is perceived as limited. Therefore, this study has attempted to elaborate a field of research to aid the port of Kristiansand and similar ports in Norway to develop into smart ports. The methodology of this thesis provides a qualitative approach for investigating the smart port potential in a small container terminal. Our study shows that the Port of Kristiansand is in an early stage towards a smart port status. Additionally, our findings indicate that there are substantial opportunities and potential for further development.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Background

"Smart ports are the only ports that will survive"
- prof. dr. Olaf Merk (Deloitte, 2017, p. 7)

The Port and Maritime industry has since the 2010s undergone a significant digital transformation and is currently in its fifth stage of evolution from a historical point of view. Further on, the Port and Maritime industry is facing new challenges such as increased pressure regarding productivity, sustainability, as well as security and safety risks. This transformation has moved ports and terminals towards a *smart port* concept in the years following 2010. In 2011, *Industry 4.0* were first defined as a term that describes the fourth industrial revolution. Since then, The Port and Maritime industry has experienced an impact from Industry 4.0, making *Port 4.0* a trendy topic in the industry (Culot et al., 2020; de la Penã et al., 2020; Deloitte, 2017). This thesis will use both terms, smart port and Port 4.0 interchangeably as they are considered to have the same meaning.

As of today, there is no globally accepted definition of Port 4.0 or smart port (Pagano et al., 2021, p. 3), however, the literature points to multiple definitions; Yang et al. (2018, p. 34) defines a smart port as a port which utilises IoT-technology to link all devices together. The definition also focuses on autonomy, meaning that all operations are fully automated. The key infrastructure of the smart port consists of actuators, wireless devices, smart sensors and data gathering centres which is accessible to the port authorities at any given time. Lastly, the definition describes that there are the fundamental drivers for smart ports are efficiency and productivity. Delenclos et al. (2018) defines smart ports as digital-based multistakeholder systems. The goal of transforming ports is to remain productive, customer friendly, efficient, and competitive. The article mentions that cooperation among the involved parties of the entire port ecosystem is crucial. Thus, stakeholders must adopt systems to embrace communication between port authorities, terminals, shipping lines, trucking and logistics companies, and off-dock storage providers to become truly effective, in addition to adopting technologies from other industries. The recurring factors in these definitions are automation, emphasising efficiency, productivity, increasing quality of services, integration of a multitude of entities, and that the technologies used match the business profile and vision of the port Karaś (2020, pp. 30–31).

In a research article from 2020, published by TransNav, it is suggested that the development towards the smart port concept is an irreversible trend and will require several years of development before reaching a mature stage (Karaś, 2020, p. 31). Yang et al. (2018) points out that: "the automated container terminal has become the inevitable development trend of the future". Smart and autonomous shipping is predicted to transfer and revolutionise the entire maritime sector during this new and digital era. Ports are a fundamental component in the maritime transport network and smart solutions are essential to boost the effectiveness of daily operations (SINTEF, 2020, p. 19). Also, a report published by Deloitte in 2017 states that going forward, only the smartest and not the largest ports will endure. This implies that the future of ports relies on automation and smart solutions, and that technological developments towards the concept of smart ports are imperative for ports to survive long-term. As ports can no longer compete from a size perspective, there is definite need for a change of direction, where optimisation of operations and efficiency should be the primary concern (Deloitte, 2017, p. 7).

1.1.1 Digital Transformation of Ports

As of today, approximately 80% of global trading activities are transported by sea, and in this digital age, modern seaports play a critical role in the global supply chain (Heilig et al., 2017; Yau et al., 2020). McKinsey & Company (2018) reveals that ports have been adopting automation in a slower pace than comparable sectors such as the warehouse and mining industry, but that the rate of adoption has increased in recent years.

Tijan et al. (2017, p. 1) describes digital transformation as: .. "the process of reshaping the business models due to, and through, the adoption and use of digital technologies with the aim of creation of setting (within the organisation and its environment) in which new possibilities (digital capabilities) are enabled and value is created." As a result of the implementation and use of digital technology, digital transformation means fundamental changes to traditional business practices (see Figure 1.1).

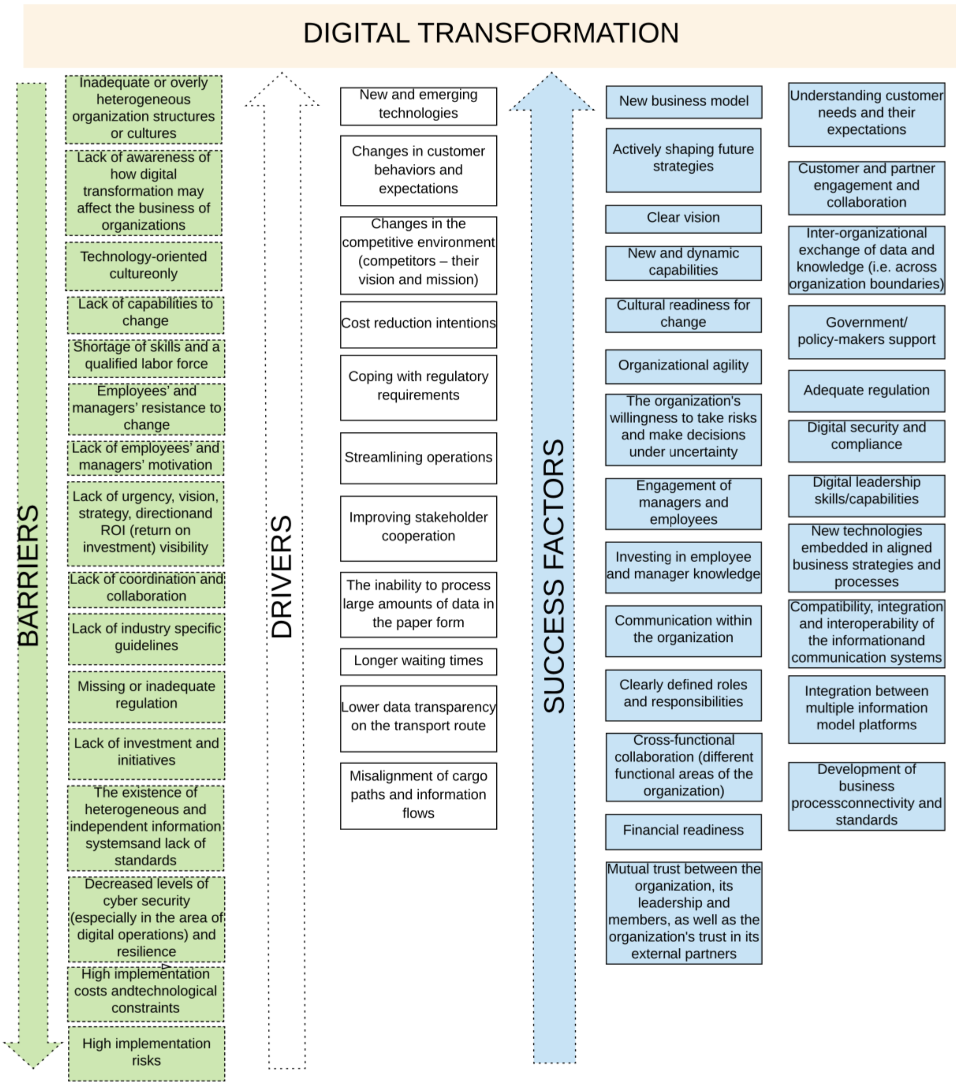

Figure 1.1: Digital Transformation in Seaports (Tijan et al., 2017, p. 3)

According to Heilig et al. (2017, pp. 1342–1343) seaports can be classified into three different generations. Ports have been part of a digital transformation process since the early 1960, where the entire sector rapidly changed with the implementation of containerisation and freight-transport. This is referred to as the first generation, where ports went from paperless procedures to utilising basic IT features in accounting or invoice-processes. With the use of EDI (Electronic Data Interchange) systems this allowed for the exchange of cross-organisational information and knowledge.

The second generation of ports in regards to digital transformation started in the early 1990s and past the 2000s. The main technological innovation that promoted safety and automation back then was the use of laser and sensor technology. This new technology provided key functionality to the port operations as they could now more accurately measure distance, locate containers and goods, in addition to prevent accidents from occurring. As such, this major shift positioned ports for the future by increasing the level of automation procedures which was a trend that continued until end of the 1990s (Heilig et al., 2017, pp. 1344–1346).

Since the early 2010s the third and current generation of ports emphasis on developing the port‘s infrastructure by employing and make use of available data and interactions among port stakeholders. This differs from the first and second generation, as they focused more on facilitating improved information flows between terminals and port communities, improving terminal automation, trading, and interaction in a local or global environment (Heilig et al., 2017, pp. 1347–1348).

Tijan et al. (2017) outlines that there are a multitude of barriers related to digital transformation of seaports. A majority of these barriers are organisational-related and are identified in Figure 1.1. Failing to digitally transform seaports can be linked to an insufficient number of qualified workers with the appropriate digital skills. As technology advances workers may not be capable of keeping up with the rapid development, which ultimately will lead to the deceleration of digital transformation (Tijan et al., 2017, p. 9).

1.2 Problem Statement and Research Questions

The intention of this study is to elaborate a field of research to aid the port of Kristiansand and similar ports in Norway to develop into smart ports. The goal of this research is to accelerate the overall smart port development by collecting relevant literature and presenting key definitions, technologies, analysing and discussing data in the light of the literature. Therefore, we will investigate the potential of developing a smart port in The Port of Kristiansand. The term *potential* in this context refers to *unrealised capabilities or the ability to develop and prepare the port for the future*. Therefore, the following problem statement has been defined:

What is the potential for Port 4.0 in the Port of Kristiansand's container terminal?

In order to answer the problem statement, we want to get an overview over the current state of smart port elements in the Port of Kristiansand‘s container terminal. By doing so, we will find *realised* capabilities. This approach also gives an insight into which capabilities are *unrealised* (RQ1). Further, we want to map out how extensive the development of smart port elements is, which is closely linked to their abilities to develop the port for the future (RQ2). We have observed that the container terminal and its operations is planned to be moved to a new area (Kongsgård and Vige). On that account, it is interesting to investigate whether this will affect the smart port potential. This is also considered important to retain the relevance of the thesis work in the future (RQ3). As a result, three research questions have been formulated to answer the problem statement:

RQ1. *To what extent are smart port elements integrated in the container terminal?*

RQ2. *How extensive is the further development of smart port in the container terminal?*

RQ3. *How will the relocation of the container terminal impact the smart port potential?*

The scope of this thesis is limited to systems, operations and technologies that are related to the container terminal. Vessels are also part of this study, but have we have limited the scope to only investigate communication between ships and the port and willingness among freight forwarders, shippers and shipping liners. Also, costs and available capital are recognised as important factors to realise the smart port development. Hence, these factors are considered crucial parts of a port‘s smart port potential. However, costs and available capital will not be considered in this thesis.

1.3 The Port of Kristiansand

The Port of Kristiansand (Figure 1.2) is located in the southern part of Norway and serves as a central junction point for industrial processing and offshore related activities with routes to the European continental market (Port of Kristiansand, 2020a, p. 4). The main goal and vision according to their strategy plan towards 2030 is to become the most modern port in Norway and act as a leading port within environmental sustainability that contributes to the sustainable conversion of the maritime industry (Port of Kristiansand, 2020b, p. 3). The Port of Kristiansand has business areas within offshore, fishing, property, container transport, cruises and ferries (Port of Kristiansand, 2020b, p. 12). However, this thesis is limited to only the container terminal, which handles around 470.751 tonnes of goods each year, making up for 14% of the total income to the Port of Kristiansand(Port of Kristiansand, 2020a, 5 and 7). The central port area is also where the port administration offices are located (Port of Kristiansand, 2020a, pp. 5–7). According to SSB (2021) (Statistics Norway), The Port of Kristiansand accounts for approximately 1,8 percent of all freight transport on the coast of Norway, with the Bergen and Omland area ranking the highest at a total market share of 33,2 percent.

Figure 1.2: Aerial View of The Central Areas (Lagmannsholmen) of The Port of Kristiansand (Port of Kristiansand, n.d.-b)

As reported by *The European Sea Ports Organisation*, ports in Europe are classified as either *small*, *medium*, or *large* in size, determined by the volume of goods handled per year, as illustrated in Table 1.1 (ESPO, 2010). There are other ways to classify a port, as pointed out in Bichou (2009, p. 11), but we wanted to give a general port classification of the Port of Kristiansand, so that the study becomes more tangible. For this purpose, throughput (volume of goods) was considered the most important parameter because of its simplicity and relevance to the size of the container terminal.

Table 1.1: Port Authority Size with Respect to Annual Goods Handled (ESPO, 2010, pp. 24–25)

Port authority size	Annual volume of goods handled
Small	Less than or equal to 10 million tonnes
Medium	Less than or equal to 50 tonnes, but more than 10 million tonnes
Large	More than 50 million tonnes

The Port of Kristiansand has an annual throughput of 1.78 million tonnes of cargo (Port of Kristiansand, 2020a, p. 5), and thus, the port can be classified as a *small port*.

The port is currently expanding their capacity and is undertaking a project which involves moving the "entire" container terminal business from the central area to a new location in Kongsgård and Vige (Figure 1.3) which is situated in the eastern part of Kristiansand. The Kongsgård and Vige port area as of today facilitates concrete production, logistics dock, offshore supplies and general cargo (Port of Kristiansand, 2020a, p. 5). The project is believed to be an expensive affair, and port-related activities as well as the income from the port's real estate portfolio will help fund the investments of the new container terminal (Port of Kristiansand, 2022).

Figure 1.3: An Illustration of The Business Areas of The Port of Kristiansand (Port of Kristiansand, 2020a, p. 4)

As the port's goal is to become the most modern port in Norway, combined with their importance in the national and international shipping industry makes the Port of Kristiansand a compelling choice regarding the problem statement of this thesis. Similar research has not been conducted in the Port of Kristiansand and is unique for this thesis.

Chapter 2

Theory

2.1 Port 4.0

As mentioned in chapter 1, section 1.1, the literature points to several definitions of smart ports. The definition provided by Yang et al. (2018), emphasises the technological aspect of smart ports. IoT, fully automated operations, wireless actuators and smart sensors are spoken of as the fundamental technological components of a smart port, with the key drivers being efficiency and productivity. The definition provided by Delenclos et al. (2018), however, puts more weight on cooperation and communication among the involved parties, without excluding the importance of technological innovation. Integration of the surrounding region as well as stakeholders and port authorities is also mentioned by Karaś (2020). Sustainability is also mentioned as a criteria for smart ports by both Delenclos et al. (2018), Karaś (2020) and de la Penã et al. (2020, p. 9). These definitions also bring up the competitive aspect of a smart port as a part of smart port development. The key words from these definitions are *efficiency, automation, digitalisation, integration*, *competitiveness* and *sustainability.* All these ideas are summarised by Douaioui et al. (2018) in two models referred as *The pillars of the smart port* (Figure 2.1) and *the smart port system* (Figure 2.2). No similar models were found in the literature review of this study, but as the model covers the various definitions that were discovered in the literature from a holistic perspective, Douaioui et al. (2018)'s models will constitute the theoretical basis of this chapter. An overview of the pillars that make up a smart port will aid in understanding the various actors, characteristics, technologies and systems that play important roles in discovering the potential of developing a smart port in an existing port.

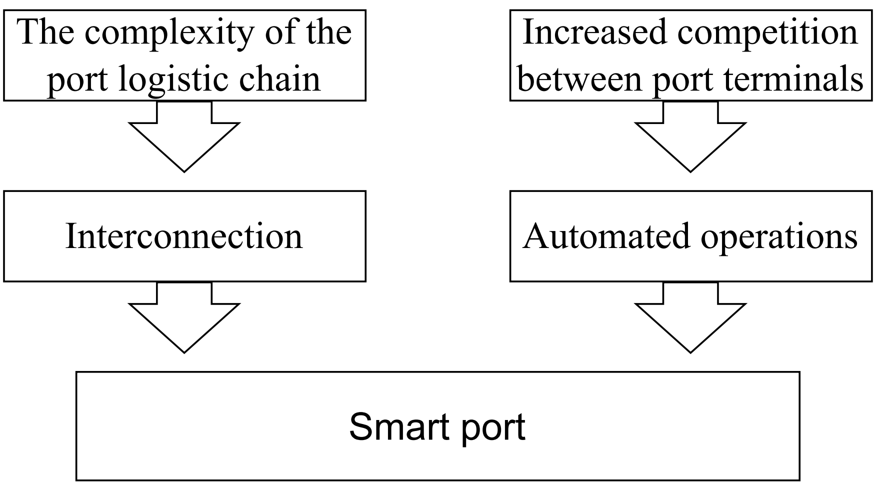

Figure 2.1: The pillars of The Smart Port (Douaioui et al., 2018, p. 3)

The smart port system (Figure 2.2) illustrates technical solutions that would facilitate interconnection and automation in a port (Douaioui et al., 2018, p. 3). Investigating the potential of implementing these technical solutions could be a starting point in order to find the degree of interconnection and automation, hence discovering the potential of developing a smart port.

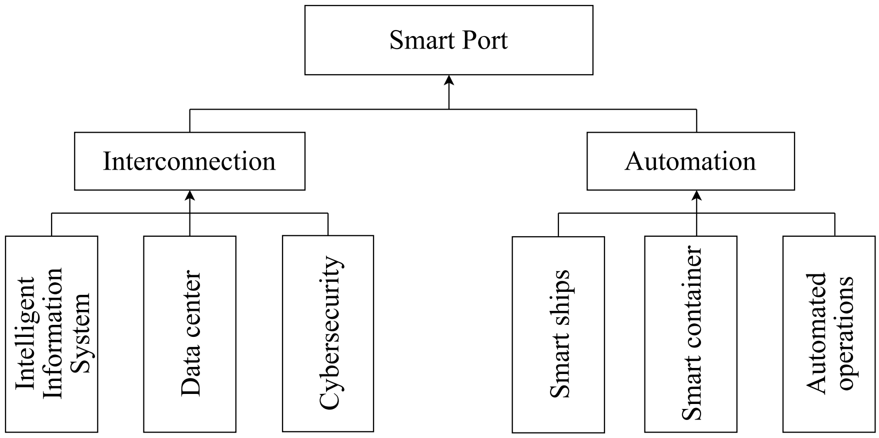

Figure 2.2: Illustration of a Smart Port System (Douaioui et al., 2018, p. 3)

The term *smart ship* was a part of Figure 2.2, but this study is limited to ports and will not go in depth on smart ships. What will be considered in this regard is communication between the ship and the port. For this to be facilitated, it is important that both operate with similar methods of communication, processes, definitions of data, and supporting system. This is elaborated in subsection 2.2.1.

As mentioned in section 1.2, the smart port potential refers to a port's ability to develop and prepare for the future. As such, it is vital to outline and map out the level of smart port elements which are integrated in the container terminal as this can clarify how extensive the further development of the smart port concept is. As shown in Table 2.1, the figure displays the five development stages towards smart port status. The model presented by Philipp (2020) ranges from the lowest stage, *stage 0*, to the highest stage, *stage 4*. In essence, the lower the development stage the port is at, the less potential the port has to be classified as a fully operational smart port.

Table 2.1: The Five Development Stages Towards a Smart Port Status (Philipp, 2020, p. 51)

Stage	Classifications of ports	Description
Stage 0	Analog port	The port has no automation at all
Stage 1	Monitor port	The port includes individual automation
Stage 2	Adopter port	All port-involved stakeholders aim to integrate their systems to achieve better communication
Stage 3	Developer port	The hinterland and the port are interconnected
Stage 4	Smart port	Fully operational smart port, connects each port with its environment and all ports globally with each other

Stage 0 refers to the *analogue level* of ports, where computerisation (i.e. automation) of processes are non-existing. Digitalisation and the willingness to implement it to add value in the port is also absent at this stage. Stage 1 (*monitor port*) revolves around individual automation of operations. Entities (e.g. port operators, port authorities) within the port manages and create their own individual systems to further enhance value. Stage 2 (*adopter* *port*) focuses on involving all stakeholders (e.g. customs, institutions, authorities), with efforts to improve communication through a system which aims to expedite the waiting process. The *developer stage*, or stage 3, connects the port and the inland from the coast through a digitally integrated environment. This stage is meant to improve the competitive situation by expanding to a larger group of stakeholders. Moreover, achieving stage 4 (*smart port*) is not possible to achieve by the port itself but can rather be viewed as a common goal for all ports globally. At this point, all ports seek out to be fully connected with each other and the industry. Lastly, technologies such as cargo tracking and transport optimisation methods are utilised (Philipp, 2020).

2.2 Port Complexity

Simon (1996, pp. 183–184) describes a complex system as: "... one made up of a large number of parts that have many interactions". Multiple institutions are typically involved in performing port functions through ownership, sharing, leasing or by the use of port assets and facilities, each with different and sometimes conflicting objectives. These institutions and functions often overlap at different levels, which increases the port complexity. This may lead to challenges in identifying who does what and why (Bichou & Gray, 2005, p. 83). As such, a port‘s logistics chain often involves a multitude of entities and often display chaotic, non-linear behaviour (Anderson, 1999; de Leeuw et al., 2013).

In the context of global supply chains, ports are as proposed by Bichou (2009, p. 239), susceptible to complexity and uncertainty issues due to the presence of new types of challenges and problems. To illustrate, typical issues could arise when transporting cargo shipped in containers. Up to 25 different entities could be involved in such a process, and thus, managing extensive procedures or tasks through various functions and organisations could prove to be challenging (Bichou, 2009, p. 239).

As a part of a global supply chain, ports play a key role in international infrastructure and are important links for regional and national trade (Port of Kristiansand, 2020b; Sarkar & Shankar, 2021). In port logistics, various activities takes places which includes positioning of containers within the yard, storage and transportation, stacking and emptying of cargo from vessels to the yard, and customs clearance (Sarkar & Shankar, 2021, p. 2). Ports are an integrated part of a *link-node distribution system*, where nodes act as interchange hubs, storage facilities, and warehouses. Water and sea terminals, as well as road and rail terminals, make up for these nodes in the network. Nodes are the physical components in transport and distribution networks, and are typically known as *terminals*. A terminal is referred to as: "... any point within a transport chain where the movement of cargo is topped or paused for *intermodal*[1] transportation, storage and warehousing, and/or any value-adding activity" (Bichou, 2009, pp. 225–226). From a logistical perspective, Bichou and Gray (2004, p. 53) points out the significance of ports as intermodal nodes. Since both passenger traffic and cargo flows through the port, ports can be regarded as logistic centres. Additionally, ports unify numerous of the supply chain participants, making them ideal as a trade channel.

2.2.1 The Port Call Process

The port call process is generally described in the literature as the process from when a ship enters a port to when the ship departs the port (DCSA, 2021; UN, 2020; Wang & Vogt, 2019). This process is complex due to the many actors and operations involved, including port authorities, which have to give permission for the ship to berth, pilots that assist in

[1] Being or involving transportation by more than one form of carrier during a single journey (i.e in a single loading unit such as containers) (Bichou, 2009, p. 230).

bringing the ship to berth, mooring personnel to fasten the ship to the berth, terminal operators for loading and unloading the ship, service providers to deal with waste and security, and agents to monitor that the process goes according to plan (UN, 2020).

For this study, the port call process is considered a crucial part of the daily operations in the container terminal because it involves information sharing between the involved parties and can provide an overview of equipment that are/can be automated in the container terminal. Thus, the effectiveness, interconnectedness and the level of digitalisation of the port call process are therefore considered as closely linked to the potential of developing a smart container terminal. Furthermore, the steps in the port call process, as defined by DCSA (2021, p. 4), are summarised in Figure 2.3.

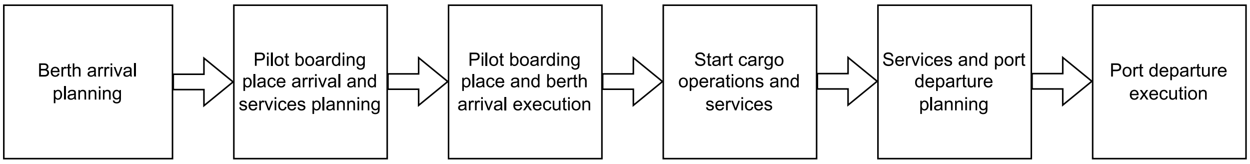

Figure 2.3: The Port Call Process, as Illustrated in DCSA (2021)

It was noted by Wang and Vogt (2019) that the time of the port call is one of the most important efficiency measures for the port, determining it's strategic competitive position. Reducing the duration of the port call process would also reduce waste and emissions, as well as increase schedule reliability (DCSA, 2020). However, Conca et al. (2018) found in their study that the main cause of ineffectiveness and lack of communication during the port call process stems from inefficient data sharing (Conca et al., 2018, p. 78). Other inefficiency factors might be inefficient communication between the actors, lack of standardised data and lack of system interoperability. Several of these factors originate from the fact that ships run into different methods of communication, processes, definitions of data, as well as supporting systems (DCSA, 2020, p. 1).

2.3 Interconnection

Douaioui et al. (2018, p. 3) propose *interconnection* of all links of the port logistics chain as a solution to the complexity by enhancing communication and cooperation between operators, key actors and stakeholders. The goal is to facilitate decision-making in real time and information sharing with the various stakeholders of the port by collecting data throughout the supply chain. However, the dissimilarities in services, activities, ownership models and organisational structure between ports as described in Bichou and Gray (2005, pp. 1, 76) suggests that the approach to interconnection will vary greatly from one port to another. As a result, there is no uniform method for creating interconnectivity within ports, and the implementation process in ports will differ from each other. In addition, the success of interconnection relies on a wide range of information, communication and control technologies (Douaioui et al., 2018, p. 3). Douaioui et al. (2018, p. 3) generalised the content of interconnection in three new pillars, namely *Intelligent information system*, *Data Center* and *Cybersecurity*, as illustrated in Figure 2.2. Only the interconnection between port entities[2] and port users[3] will be considered due to the limitations of this study.

[2]Port operators, port authorities, stakeholders, customs and other functions that operate in the port.

[3]Port users can be divided into three groups: shipping liners (e.g. Color Line, Nor-Cargo), freight forwarders (e.g. DB Schenker, DHL, Kuehne + Nagel) and shippers (e.g. any entity who transports or receives goods by sea, land, or air) (Yuen et al., 2012, p. 34).

2.3.1 Interoperability

As a part of the interconnection in ports, the term *interoperability* emphasise on: "... the capability of diverse systems and organisations to operate and work together" (Bichou, 2009, p. 21). Since ports are complex functions, interoperability should as claimed by Bichou (2009), be met at three different levels; *technologically*, *operationally*, and through *communications*.

According to Jarašunienė and Cižiūnienė (2021, p. 6), *technological interoperability* refers to the transferring of data in a secure manner through a system. IoT is an example of such a system and will be covered more extensively in subsection 2.5.4. *Operational interoperability* is as suggested by Bichou (2009), the port‘s capability to manage ships of various sizes and types, as well as the goods they are transporting. Moreover, in order to achieve a high degree of interoperability, being able to incorporate several intermodal systems (e.g. transport by railway, road, or sea) in the port is key. Efficient and timely *communications* within the port community are vital to warrant successful port operations. This allows for more refined planning of port activities, and thus, results in faster exchange of various data and information (Bichou, 2009; Jarašunienė & Cižiūnienė, 2021).

2.3.2 Intelligent Information Systems

An intelligent information system keeps traffic and operations synchronised at the maritime terminal by improving fluidity, visibility, reliability and security through continuous data and information exchange (Douaioui et al., 2018, p. 4). The term *Intelligent* might appear as rather vague, therefore, information systems that ensure the above benefits will be considered in this section. These systems will be required to store, manage, analyse, and communicate information and knowledge between different stakeholders. However, the required data for doing so is obtained by other systems that Heilig and Voß (2017) called *enabling technologies*. These technologies are essential for measurement, collection, and transmission of data and are listed in Table 2.2.

Table 2.2: Enabling Technologies (Heilig & Voß, 2017)

Enabling Technology	Description
GPS / DGPS	An extension of conventional GPS-systems to increase accuracy. Fixed reference stations communicate with satellites and receivers installed on top of transport and stacking equipment. This makes tracking of movement of containers and vehicles possible, and can serve as navigation systems for unmanned vehicles and equipment.
Electronic data interchange (EDI)	Paperless and standardised communcation between stakeholders for increased efficient port operations and integration of the logistics chain, coordination and performance. One standard supporting such communication is called UN/ EDIFAC. The standard defines several EDI message types supporting port operations
Radio-frequency identification (RFID)	Enables contactless, automatic identification and remote sharing of information by utilising radio waves. The system consists of of a data-carrying transponder, the RFID tag, and a RFID reader. Sensors might be implemented to measure physical values, such as humidity and temperature (e.g. in containers), but can also be used for authentication through gates and toll collection.
Optical character recognition systems (OCR)	Automatic pattern recognition making it possible to read container numbers, identification of vehicle licence plates and damage inspection. Generally applied to gates to automate administrative and checking procedures
Real-time location systems	Constant, live tracking of tagged objects. RFID can be used to obtain location of objects.
Wireless sensor networks	A large system that contains interconnected wireless sensors in a specific area to monitor physical conditions like temperature, humidity and position.
Mobile Devices	The sensing and computational capabilities of smart phones and tablets can be utilised and applications can be created for information sharing and interaction between various actors.
Wireless Network	A highly reliable wireless network is crucial for devices that require a consistent connection to operate.

Following the enabling technologies, Heilig and Voß (2017) describes nine information systems used in ports, which uses enabling technologies. All nine information systems are listed and explained below.

Port Community Systems

Port community systems (PCS) can be defined as electronic systems that connect key stakeholders (including port users, terminal operators, port authorities and customs) in relation to the port and their ICT system through systems that facilitate seamless flow of data. The goal is to enable secure exchange of information to keep the port competitive and effective by connecting the transport and logistics chains (Carlan et al., 2016; EPCSA, 2011; McKinsey & Company, 2018). As Carlan et al. (2016, p. 54) mentioned, PCS can involve several functionalities, like navigation, which involves lock planning, berth reservation (port call) and pre-notifications. Improving this communication is one way to reduce the time of the port call process, as elaborated in subsection 2.2.1. Other functionalities mentioned in Carlan et al. (2016) are notifications regarding dangerous goods, customs declarations or inland orders can also be communicated through port community systems.

Vessel Traffic Services

Vessel traffic services collect, analyse, and communicate information mostly related to navigating vessels in tight waterways and port areas. Vessel movement reporting systems, radar systems, radio communication systems, traffic signals, video surveillance systems and automatic identification systems (substitute for radar systems) are the most common enabling technologies for vessel traffic systems. The systems that provide real-time information on vessel movement and sea traffic can also be used to improve vessel scheduling, berth allocation and other activities related to vessels (Heilig & Voß, 2017).

Terminal Operating Systems

Terminal operating systems (TOS) are information systems that support terminal-related planning and management activities. Information from different terminal operations is collected, stored, managed, analysed, and communicated through these systems with a goal of interconnecting technologies, information systems, and applications in a container terminal, hence, providing an overview over essential terminal processes. Optical character recognition, GPS, real-time location and radio-frequency identification are enabling technologies to monitor cargo flow in such systems. Then, it is essential to use EDI standards like UN/EDIFACT [4] in order to communicate the information to external parties (Heilig & Voß, 2017).

Gate Appointment Systems

Gate appointment systems are platforms used to plan transport appointments to improve cargo flow and reduce emissions and waiting time (Heilig & Voß, 2017). The terminal operator limits the number of appointments for different time windows, then truckers make appointments to pick up or drop off containers during the relevant time window (W. Zhao & Anne, 2013).

Automated Gate Systems

These systems incorporate automatising gate procedures like checking container damages, identifying and allowing access for truck drivers to enter or exit the terminal and reading container data. Such subjects can be identified using optical character recognition and radio-frequency identification. Automatising time consuming processes like gate registration may drastically reduce peak-hour bottlenecks (Heilig & Voß, 2017).

[4] Internationally agreed upon standards, directives, and guidelines for electronic exchange of data between digital information systems (UNECE, n.d.).

Automated Yard Systems

An *automated yard system* consists of a safety laser scanner which measures the location of the trucks entering or exiting the bay station. Signals in the form of light guide the driver and notify whether if he/she should advance forward or retract backwards. The driver‘s safety is ensured by confirming that they have left the vehicle by using a smart card at the bay station. An automatic transfer crane (ATC) then lift of the container from the truck using the smart card data. Next, the crane system moves the container autonomously to its position within the yard or vice versa. Reliability and accuracy are crucial factors for this procedure, and are heavily reliant on precise container location information to be executed properly Heilig and Voß (2017).

Intelligent Transportation Systems

An ITS, or *intelligent transportation system* improve the efficiency and safety of transport systems. By using detailed analytics, ITS gather real-time data from multiple sources (e.g. vehicle based, road-based or transport network-based). Port‘s benefit from information regarding traffic congestion, accidents or other road-related bottlenecks, as the the goal is to increase efficiency (i.e. improve the cargo-handling throughput). Moreover, the data gathered by the intelligent information system are not necessarily collected in a compatible format, and as such, needs to be converted and verified into a format of which is understood by the ITS (Heilig et al., 2017).

Port Road and Traffic Control Information Systems

Unlike *intelligent transportation systems*, *port road and traffic control information systems* are more driver focused. *Port road and traffic control information systems* are as described by Heilig and Voß (2017) the procedure of measuring and controlling current traffic flows within the port area and inform vehicle drivers about the situation. Also here, real-time data is collected, and enabling technologies such as vehicle detection systems which consist of actuators and sensors are utilised to give a more detailed picture of the conditions (Heilig & Voß, 2017).

Port Hinterland Intermodal Information Systems

Stage 3 of the smart port development are as mentioned in Table 2.1, the phase where the port and hinterland are interconnected. Between the inland logistics network and the port, further improvements can be made by establishing a more efficient transportation system and transparency regarding cargo movements. The solution might be PHIIS, or *port hinterland intermodal information systems*. For example, web-based portals could serve as plannings tool for intermodal transportation. Utilising dynamic data from transport operations and other terminals could give an overview of intermodal terminals and their connections, and thus, boost the port‘s overall performance (Heilig & Voß, 2017).

2.3.3 Datacenter and Cybersecurity

Data Center

A data center is located in a physical facility as racks of metal enclosures containing critical computing resources essential for operations (e.g. data storage) (Kant, 2009, p. 2940). As the exchange of information and data between software and systems increase at a port, so will the need for a data center dedicated to the port to store and analyse the data (Douaioui et al., 2018, p. 4).

Cybersecurity

The risk for cyberattacks such as information theft, remote control of computer systems and sabotage increases with increased digitalisation, and as ports are considered essential links in supply chains, they may become targets for criminal attacks or terrorism. The consequences of such an attack might be devastating, and can spread to the entire supply chain (de la Penã et al., 2020; Douaioui et al., 2018; Gunes et al., 2021). A report published by The European Union Agency for Cybersecurity provided guidelines for managing risks related to cybersecurity in ports. Four steps to address cybersecurity are illustrated in Figure 2.4 (ENISA, 2020, p. 10).

Figure 2.4: Cyber risk management phases (ENISA, 2020, p. 10)

The report also includes guidelines and models for port operators to follow throughout the four phases, where the first phase encompasses the identification of cyber-related assets and services that should be addressed. Then, the risks are evaluated in the second phase. In the third phase, measures to deal with those risks are identified, and the fourth step involves doing an evaluation of the maturity level of the cybersecurity in the port, and improving where needed.

2.4 Competition between Port Terminals

Ports and terminals earn their income by charging ships and/or cargo for using their facilities and services (Stopford, 2009, pp. 83, 235). The competition between ports that serve within the same region therefore means attracting cargo and ships to their ports (Stopford, 2009, p. 81). The literature suggests that expanding to a smart port will increase the competitiveness of the port (section 2.1). Therefore, if the competition in the port market is significant, one can assume that the willingness to adapt and use new technologies among the involved parties of a port will increase. Willingness to adapt can be related to *Lack of employees' and managers' motivation* and *Employees' and managers' resistance to change* as mentioned in Figure 1.1. Lowering certain barriers of digital transformation such as these could contribute to increase the overall smart port potential.

2.4.1 Porter's Five Forces

The Porter's Five Forces framework can be regarded as a strategic business tool used to acquire an overview of an industry's competitive climate (Isabelle et al., 2020, p. 29) (Figure 2.5).

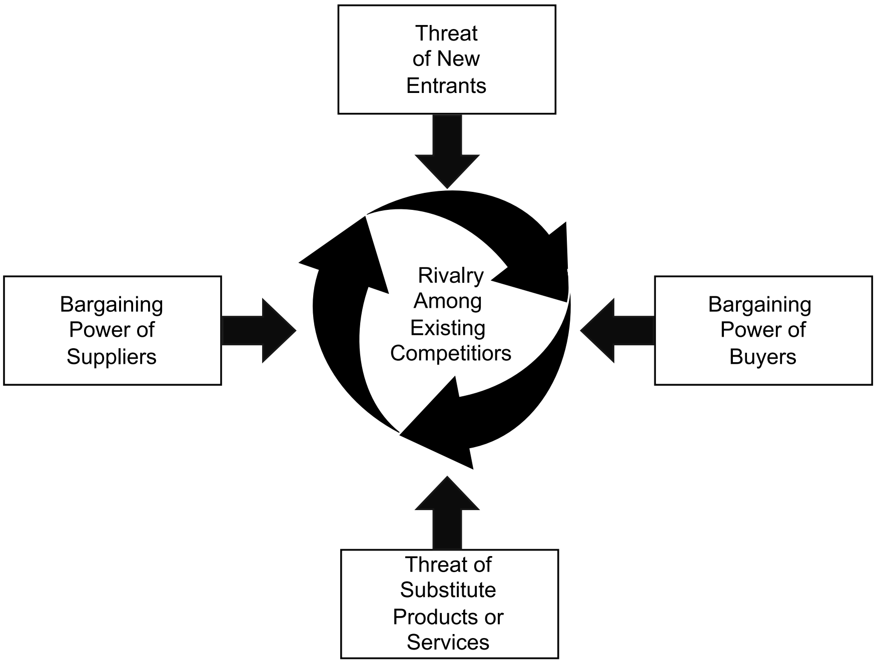

Figure 2.5: Porter's Five Forces (Porter, 2008, p. 4).

Five competitive factors that drive competition between organisations in the microenvironment can be identified: (i) the threat of new entrants, (ii) the bargaining power of buyers, (iii) the bargaining power of suppliers, (iv) the threat of substitute products or services, and (v) the rivalry among existing competitors (Bruijl, 2018; Porter, 2008).

Threat of New Entrants

Porter (2008) suggests that newcomers must lower their prices to attract customers from companies with a great number of customers. However, for ports, lowering operational costs alone may not be sufficient to attract port users from a nearby competitor. Shippers must consider size restrictions regarding water depth and container-ship capacity of the port, difference in transit time and fuel costs between the alternative ports, rail and road transport costs, as well as the capacity in chokepoints (Stopford, 2009, p. 355). Further, starting up a port requires capital to buy cargo handling equipment (e.g. cranes, port lift trucks), build facilities, obtain a favourable geographic location, hire employees and other elements that are crucial for a port to operate. This implies that the barrier related to capital requirements for new ports is high. A favourable geographic location for a port includes effectively integrated land transport systems and appropriate water depths for larger ships (Stopford, 2009, p. 81). Proximity to international shipping routes is also a great advantage regarding the location of a port. Such areas might already be occupied by incumbents and might be difficult for newcomers to obtain. The longer the port has been operating, the more experience it has earned, which also adds an advantage to incumbents. Company name and reputation may also bring an advantage if they are are known to provide effective and reliable services for their customers.

The entry barriers for ports are quite high, mostly due to high startup costs and the difficulties of meeting the geographic requirements of a port. However, there is a possibility for governments to reduce these barriers. It can lower startup costs by investing in the new port or facilitate a certain area for port activity by sponsoring infrastructure development, as was done in China in the 1990s (Stopford, 2009, p. 376). Governments can also rise the entry barriers by requiring licenses and permits, sponsoring local and national operators and delaying the planning and approval process of projects related to new ports (Bichou, 2009, pp. 211–212).

Bargaining Power of Suppliers and Buyers

A supplier has a high bargaining power if the amount of suppliers in the industry is more concentrated than the amount of buyers. The supplier may also be powerful if it does not depend heavily on the industry it sells to, if they offer differentiated products or products that are unsubstitutable, or if the buyer would face large switching costs [5] for switching supplier. These suppliers can create more value for themselves by charging higher prices or by limiting quality and services. However, if the supplier experiences tough competition, and if customers can easily switch to a different supplier, then the bargaining power will be weakened (Porter, 2008, pp. 13–14). As ports are considered a supplier of port services, they may experience a high bargaining power if they do not depend heavily on the port users, and if they are attractive to new port users. Also, if the industry contains a high number of port users, but the availability of ports are limited, the bargaining power of the port will be strengthened.

The opposite of powerful suppliers is powerful buyers. Such buyers can demand reduced prices and increased quality or services. This may take place if there are few buyers in the industry, if buyers face low switching costs or if the products and services are undifferentiated (Porter, 2008, pp. 14–16). Port users are powerful buyers if they can easily switch between ports, and if they can threaten to integrate into the industry by owning and operating their own ports and terminals (Bichou, 2009, p. 212).

Rivalry Among Existing Competitors

According to Porter (2008), when the competition is high, profitability suffers within the industry, and organisations may learn to offer discounts and introduce new products, or run advertising campaigns and improve service. Porter establishes that *intense rivalry* results if the following conditions are present; the growth within the industry is moderate, several competitors compete for the same market share or are roughly equivalent in size and power, lack of understanding one another, different competing approaches, and differing goals hinder companies from reading each other's signals well (Porter, 2008, pp. 18–21).

To further expand on the rivalry among existing competitors, a port's competitiveness can be broken down into eight key determinants (Tongzon & Heng, 2005). Each of these factors are described on Table 2.3 (barriers) the next page.

[5] Fixed costs that are associated with the customer's change of suppliers. This might involve a change in software, training employees or converting machinery. High customer switching costs means difficulties for competitors to gain customers (Porter, 2008)

Table 2.3: The Eight Key Determinants of Port Competitiveness (Tongzon & Heng, 2005, p. 408)

Barrier	Description
Port (terminal) operation efficiency level	The port‘s efficiency levels are for example a measurement of the time it takes for containers to be handled at ports (Tongzon & Heng, 2005, p. 409).
Port cargo handling charges	Handling charges in ports refer to fees associated with transport or packing of goods and containers. For port users, services associated with cargo handling, total charges are the most crucial factor. Lower service charges often attract more shipping liners as they can contribute to reduce operating costs (Trujillo & Nombela, 1999, pp. 41–43).
Reliability	Reliability greatly affects the port‘s performance. The term reliability is used to describe overall predictability and the port‘s ability to adapt to changes or rescheduling. Frequent delays due to meteorological conditions, system malfunctions or failing equipment can cause shipping firms and shippers to lose out, thereby making businesses unprofitable (Tongzon & Heng, 2005, p. 409).
Port selection preferences of carriers and shippers	One cannot take for granted the loyalty of a port client, and in a competitive market environment, carriers and shippers usually prefer ports that have a track record of both being reliable and offer quality services. Large companies greatly influence the port‘s container traffic (e.g. revenue) and losing clients is considered a constant risk (Fleming & Baird, 1999; Notteboom & Winkelmans, 2001).
The depth of the navigation channel	Shallow water depths may impose problems to larger container vessels. As such, port‘s might lack the ability to adequately accommodate these. The efficiency of a port is dependent on cargo flows without interruptions, therefore, efficiency might suffer if the connections between land, ports and end-destinations are insufficient (Peters, 2001, p. 11).

Continued on next page

Table 2.3 – continued from previous page

Barrier	Description
Adaptability to the changing market environment	Identifying customer needs and willingness to adapt to changing conditions is vital and requires the port management to continuously re-assess their strategies (Notteboom & Winkelmans, 2001, pp. 78–79). In order to ensure the longevity and success of seaports, those who focuses on being consumer-driven are ultimately those who will succeed in the long-term (Tongzon & Heng, 2005, p. 409).
Landside accessibility	For ports, having access to the shoreline and having direct access to main roads, rail lines, and inland waterways can be viewed as advantageous. The growth outlook of a port is all affected by these factors. When port users decide whether or not to chose a certain port for their operations, connection to the inland is considered. Therefore, a port‘s geographical location might be a limiting component compared to other ports (Fleming & Baird, 1999, p. 390).
Service differentiation	Service differentiation means being able to contribute superior or unique services for the port users, which affects both the co-operation dynamics and competition. The level of service differentiation can vary in for example quality or within a specific category (Cui & Notteboom, 2018, p. 77).

Pérez et al. (2020) found in their study that the most efficient ports are those who are larger in size (area) and are specialised in containers, general cargo, and liquid bulk. Similar findings regarding technical efficiency as a result of specialising in these types of cargo were found in Tovar and Wall (2015). Moreover, Pérez et al. (2020) elaborates that smaller ports who do not offer any or a low degree of specialisation often share the hinterland with larger ports which, in addition to the domestic market. Consequently, ports with specialised services are more competitive in these cases.

Threat of Substitute Products or Services

Similarly to rivalry among competitors, Porter (2008) states that the profitability of an industry suffers when the threat of substitutes is prominent. The term *substitute* can be understood as a product or service that is of similar function as other products or services within an industry. In the context of ports, alternative transport systems such as land transportation (e.g. semi-trucks, railway) for cargo shipping can be considered a substitute product, because the need for port services could be avoided. Longer distances (e.g. cross-continental transport) can however be unfavourable for land transport, therefore, *short-sea* *shipping (SSS)* is considered to be the most viable option (Medda & Trujillo, 2010; Stopford, 2009). A definition of the term has been provided by the European Community Shipowners' Associations: "short sea shipping' is the movement of cargo and passengers by sea over short distances" (ECSA, 2016).

Gelareh et al. (2013, pp. 3307–3308) propose several benefits of transporting cargo by sea (over shorter distances) which include: the ability to transport a large quantity of goods and materials, cost-efficiency (allows companies to sell their products at a lower rate), and safer than road transport (e.g. less pollution and minimal risk of accidents) when accounting for volume. As reported by Medda and Trujillo (2010), infrastructural upgrades are not needed to compensate for the increased volume. Moreover, there are also disadvantages to short-sea shipping. Firstly, SSS can be regarded by customers as an outdated method of transportation. This is due to the customers alternating expectations to pricing, quality, and service. Next, SSS might impose poor door-to-door services as a consequence of the logistical challenges in shipping. SSS is also reliant on adequate interconnection to the inland and hinterland, and maritime (e.g. port and port services) efficiency (Medda & Trujillo, 2010, p. 290).

2.4.2 Augmented Porter's Five Forces

Bjørnenak (2019) and Isabelle et al. (2020) points out that the Porter‘s Five Forces framework has in recent years encountered critique for being too flawed and constricted, as there is too much focus on how values are seized and too little on how they are created. However, the model can still be used to provide a comprehensive picture of the competitive situation. Shamir and Johnson (2014) proposes that P5F model has: "seem to become frozen in time", which can interpreted as the model has not evolved since its inception back in 1979.

To elaborate on this critique, Isabelle et al. (2020) discuss in their article if the P5F framework is still relevant in a modern and competitive environment of the 21st century. This statement is also supported by Shamir and Johnson (2014). Companies in the 21st century operate under more complex conditions than they did during the 20th century, and therefore the existing P5F framework is claimed by Isabelle et al. (2020) to have deficiencies, and thus, decision-making processes can be faulty as a result. Along with the original five forces, four additional forces have been identified by both Isabelle et al. (2020, p. 37) and Shamir and Johnson (2014, p. 9) as a contribution and extension to the original model; *competitor‘s level of innovativeness*, *threat of digitalisation*, *exposure to globalisation*, and *industry exposure to de/regulation activities*. Figure 2.6 illustrates the four additional forces.

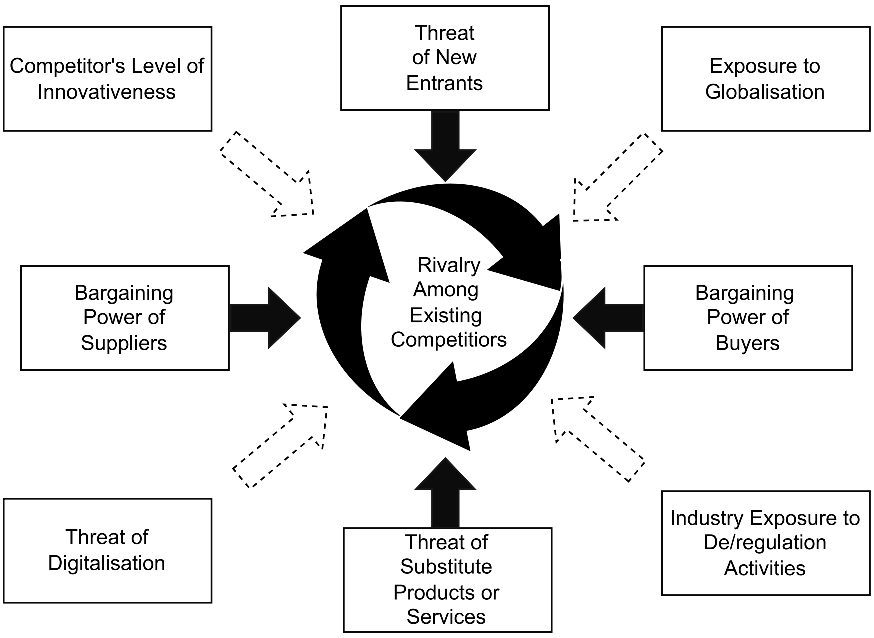

Figure 2.6: Augmented PFF Model (Isabelle et al., 2020; Shamir & Johnson, 2014)

Competitor‘s Level of Innovativeness

The level of *innovativeness* refers to a company‘s ability to create a competitive edge (Isabelle et al., 2020, p. 34). Innovation is considered by Shamir and Johnson (2014, p. 6), as: "... a force that also drives industry competition". Also, Shamir and Johnson (2014) point out that adaptation will result in a stronger competitive advantage for one who is better suited to the industry. The port‘s container terminals can for example utilise better cargo handling technologies or develop technologies for automatic identification. Activation of real-time data usage is also viewed as beneficial and can result in enhanced responsiveness for operations and procedures. Increased responsiveness can solve many issues in regards to errors or alterations, and thus, boost terminal efficiency (Heilig et al., 2017).

Threat of Digitalisation

In a literature review from 2020, Reis et al. (2020, p. 443) made an attempt to define the term *digitalisation* based on multiple definitions found in 16 other scientific works, to both shed light on that the term is being used indistinctively, and to clarify the general concept to avoid misconceptions. The new definition was as following: "digitalisation is the phenomenon of transforming analogue data into digital language (i.e. digitisation), which, in turn, can improve business relationships between customer and companies, bringing added value to the whole economy and society". As stated in Isabelle et al. (2020, p. 34), the further an industry is digitalised, the more intense the competition will be within it. Brunila et al. (2021, p. 5) identifies that the level of digitalisation which the port holds, can be used as a bargaining chip in a competitive environment. Still, compared to larger ports, smaller ports might fall behind in this area due to resource or budget constraints. Lastly, Shamir and Johnson (2014, p. 10) identifies that the threat of digitalisation is high when highly digitalised competitors exist within an environment.

Exposure to Globalisation

By definition, the term *globalisation* is from the viewpoint of Yeates (2005): "... a highly contested term". In the context of globalisation, one understands the emergence of extensive networks of economic, cultural, social, and political relationships and processes that reach far beyond national borders (Yeates, 2005, p. 1). For this reason, *exposure to globalisation* goes beyond the limitations of this study and will not be taken into account during the remaining part of the thesis work.

Industry Exposure to De/Regulation Activities

Favourable regulations imposed by governments allow industries for unrestricted operations and more favourable environment to take place (Isabelle et al., 2020, p. 36). An important aspect mentioned by Adamowicz (2018, p. 1), is that for the entire global economy to profit, supportive conditions are critical for seaports to progress and operate efficiently. An example of such a regulation is the legislative act developed by the European Union regarding regulation of port services and financial transparency of ports. These regulations are meant to act as supportive conditions for member states of EU/EEA (European Union, 2017).

2.5 Automated Operations

"...the automated container terminal has become the inevitable development trend of the future." (Yang et al., 2018, p. 36)

Automation is a key aspect of smart ports and emphasised by most of the authors from the literature study (de la Penã et al., 2020; Molavi et al., 2020; Yang et al., 2018). A report published by McKinsey in 2018 suggests that by investing in automation technology, ports lay the foundation for Port 4.0, and thereby creating long-term value for all involved entities such as suppliers, port operators and clients (McKinsey & Company, 2018, p. 2). Moreover, ports are operated with heavy machinery and equipment making safety a concern in the daily operations within the ports. By fully or partially automating work procedures, the physical environment can develop into safer and more predictable surroundings for the employees (McKinsey & Company, 2018, p. 2). High levels of automation and qualified stevedores characteristic of container handling contribute to greater efficiency of container ports and terminals (Pérez et al., 2020, p. 244).

2.5.1 Automated Equipment

An automated container terminal consists of quay cranes (QCs), automated guided vehicles (AGVs) and yard cranes (YCs) (Luo & Wu, 2020, p. 1). An AGV is an autonomous vehicle guided by markers or wires, or which utilises vision, magnets or lasers for navigation. DGPS-systems can also serve as a navigation system for such vehicles, providing and accurate positioning of the vehicle (DGPS is elaborated in Table 2.2). This system will also facilitate communication between vehicles (Heilig & Voß, 2017, p. 181). An AGV's task is to transport containers between the quayside and the storage yard (Luo & Wu, 2020, p. 1). Quay cranes are also known as *STS cranes*, or *Shore-To-Ship* cranes (PEMA, 2016, p. 15). A simple setup of an automated container terminal is illustrated in Figure 2.7 by Q. Zhao et al. (2019, p. 1). In this article, the equipment was called AQCs, AGVs and AYCs, emphasasing that all equipment is automated. In the process described, AQCs assist the AGVs with loading/unloading operations by moving cargo on or off the ship to the container terminal.

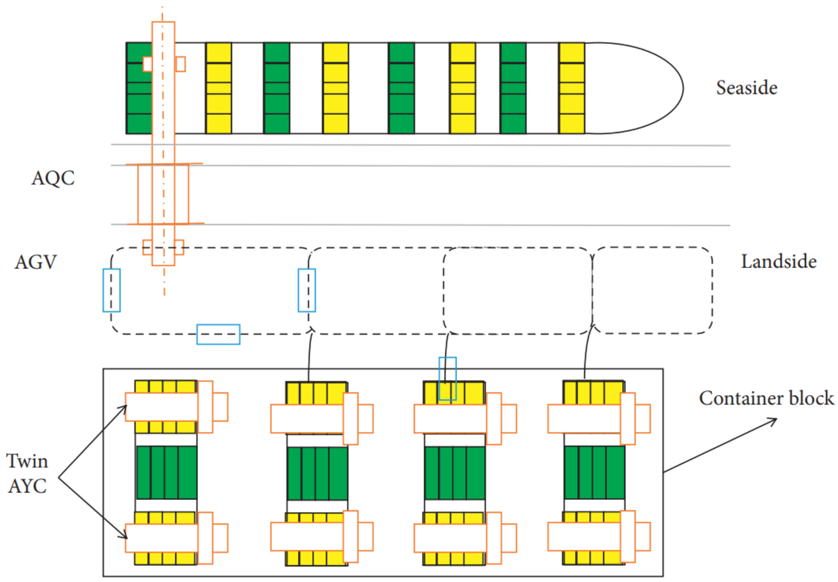

Figure 2.7: Overview of an Automated Container Terminal (Q. Zhao et al., 2019, p. 2)

The AGVs transport containers between the AQCs and the yard, and the AYCs stack containers where they are stored until further processing (Q. Zhao et al., 2019, p. 1). However, based on the findings in Luo and Wu (2020), the automated equipment mentioned in this section is greatly dependant on accurate scheduling. Poor scheduling may cause longer waiting times and thereby reduce the operational efficiency in loading sequences.

2.5.2 Equipment-Control Systems

The term *equipment-control systems* refers to methods or systems that aid various machines and equipment to achieve an improved operating experience (McKinsey & Company, 2018, p. 7). As specified by de Canete et al. (2011, p. 137), "control systems are aimed to modify the behaviour of an existing system to perform in a desired way". Also, these systems provide additional information, and thus streamlines decision-making processes. It is important to point out that there is no universal system that can be integrated into the port‘s equipment and machines. Consequently, this adds to the overall complexity (McKinsey & Company, 2018, p. 7).

Automated Cranes

In the report published by PEMA (2016), the concept of AQCs is based on remote controlled operations, where the driver‘s cabin is no longer required. This can be interpreted as *partial automation*, as the cranes are remotely operated. Quay cranes are equipped with the use of the latest advances in imaging technology, sensor technology (e.g. laser, infrared based), and crane management information systems (conveys the status of the crane). Remote controlled crane operations provide added safety for the container terminal employees due to the separation of humans and machines. Another benefit of AQCs is in cases where the crane itself is of considerable height. Due to the physical space between the cargo and the crane operator, the vision might be restricted, and thus, impairing the efficiency or create hazardous situations. From an external control room where the crane is remotely controlled, operator performance and efficiency could be enhanced by using camera technology with for example better zooming capabilities or with added viewing angles (PEMA, 2016, p. 15).

Automated Mooring System

An automated mooring system, or *AMS*, is a system which consists of multiple machines that automatically *moore* (i.e. dock) a vessel without the use of ropes. The AMS system takes advantage of suction (e.g. vacuum cup) or magnetism-based technologies to adequately attach the machines to the side of the vessel. By implementing such a system, the safety of the container terminal‘s employees are greatly enhanced as it removes the need for physical interaction, and reduces the risk of crushing injuries or in worst case, fatality. Within the berth (i.e. the area within the dock meant for vessels), cargo handling operations can also be optimised as the AMS system ensures less roll and surge of the vessel (Asian Development Bank, 2020; Piris et al., 2018). As reported by Piris et al. (2018), the engines of the an AMS system consumes 75% less fuel than traditional mooring systems, therefore, utilising AMS technology could lead to a reduction of carbon dioxide emissions.

2.5.3 Smart Container

A smart container allows tracking and remote monitoring of physical conditions like temperature, vibration or falls and other events like unexpected opening or inspections of the container. It is also possible to track the location of the container and send alert messages to stakeholders in the case of an emergency (Yau et al., 2020, pp. 83391–83392). A GPS-system can be used to track the movement of containers, and DGPS (explained in Table 2.2 can be used for the same purpose for more accurate positioning within a container terminal (Heilig & Voß, 2017, p. 181). Heilig and Voß (2017) mentioned RFID-based electronic seals (RFID is explained in Table 2.2) as a way to increase security related to containers. This seal is attached to the locking device on the container, and will detect an attempted removal. The RFID can also be used to tag the container, allowing information to be retrieved by RFID readers in different points of the logistics chain.

2.5.4 Internet of Things (IoT) and 5G

Gubbi et al. (2013) defined Internet of Things (IoT) in smart environments in their article as an: "... interconnection of sensing and actuating devices providing the ability to share information across platforms through a unified framework, developing a common operating picture for enabling innovative applications. This is achieved by seamless ubiquitous sensing, data analytics and information representation with Cloud computing as the unifying framework". This definition is similar to the one found in Yang et al. (2018), defining IoT as "...a network of items including sensors and embedded systems which are connected to the Internet and enable physical objects to gather and exchange data". Yang et al. (2018) also report that IoT technology in smart ports can be useful to build *interconnected* platforms.

Within these platforms, smart applications can be deployed with a more efficient information flow between equipment and infrastructure. In regards to efficiency, IoT can provide significant utility and as a result, boost *operational* efficiency, and improve port security. Lastly, it is critical for the port to have: "... a clear business case in mind when planning its IoT implementation" as reported by Deloitte (2017, p. 14). The report also suggests that a *smart port* is not the final stage of development. As such, IoT can be considered as a future platform and the next phase of development where communication between different ports and systems make up for a *smart port network* (e.g. interconnection between different ports).

Based on Khuntia et al. (2021), another important part and driver of IoT is the use of *5G technology*. 5G enables reduced latency, rapid data transfer speeds and enhanced mobile coverage. In comparison to 4G/LTE, 5G is capable of supporting 100 times more devices per unit area. Additionally, 5G is believed to unlock the potential of IoT far beyond what can be accomplished today with existing technologies.

2.6 Smart Container Terminal

The authors of this thesis have attempted to develop a model (Figure 2.8) that highlights crucial components that make up a smart container terminal. The purpose of the model is to serve as a guideline for finding the potential of developing a container terminal into a *smart container terminal*. While the model could be applicable to the entire port or other port terminals, this study has focused on container terminals and has therefore been named *Smart Container Terminal*.

The model originates from Douaioui et al. (2018)'s representation of the smart port concept with inputs from other findings from the literature discussed in this chapter, as well as our own impressions and perceptions. Our impression is that Douaioui et al. (2018)'s model (Figure 2.1) is a simplified representation of the smart port concept. This simplification can make it challenging to find the potential for a smart port or map the degree of smart port, because the figure does not point to specific areas within each pillar. However, we still consider the model as a basis for expansion, because of its simplicity and clear structure. Additionally, the model covers a substantial part of the literature on smart ports, and thus serving as a suitable starting point.

The term *increased competition* from Douaioui et al. (2018)'s model has been swapped out with *Competition Between Port Terminals* because the purpose is to map out the competitive situation between ports as of today, and not if the competition has increased or decreased. Moreover, as argued in subsection 2.3.2, the term *intelligent* appears to be rather obscure. In essence, an information system can be viewed as intelligent, without referring to it as intelligent. Limited literature regarding intelligent information systems was discovered during the literature study, and therefore, this thesis is focused towards modern information systems that utilise new technology. The model starts from the bottom with two key drivers for developing a smart container terminal. These drivers are *Port Complexity* and *Competition Between Port Terminals*. *Port complexity* is divided into port entities and users, and is considered a key driver for interconnection, meaning that an increase of port complexity would also increase the demand for interconnection.
The second key driver, *Competition Between Port Terminals*, is treated as a driver for smart port development because it encourages technological advancement and innovation. This argument is also supported by Yau et al. (2020) and Heilig and Voß (2017). It was also discussed in section 2.4 how competition might contribute to increasing the willingness to adapt and implement new technologies among the management and employees in the port.

Thus, *Competition Between Port Terminals* encourages the development of *Automated Operations*, which, in this context refers to automation of physical operations in the container terminal. Both *Automated Operations* and *Interconnection* are enabled through *Technical Solutions*, which represents the core of the model. *Technical Solutions* is divided into three categories. The first category are the solutions that facilitate interconnection, namely *Enabling Technologies* and *Information Systems*. The second category are technical solutions that are needed to provide both interconnection and automated operations (*Cybersecurity*, *Data Center* and *Internet of Things* (IoT)). The third category is technical solutions that are needed to automate operations in the container terminal (*Automated Equipment* and *Equipment Control Systems*).

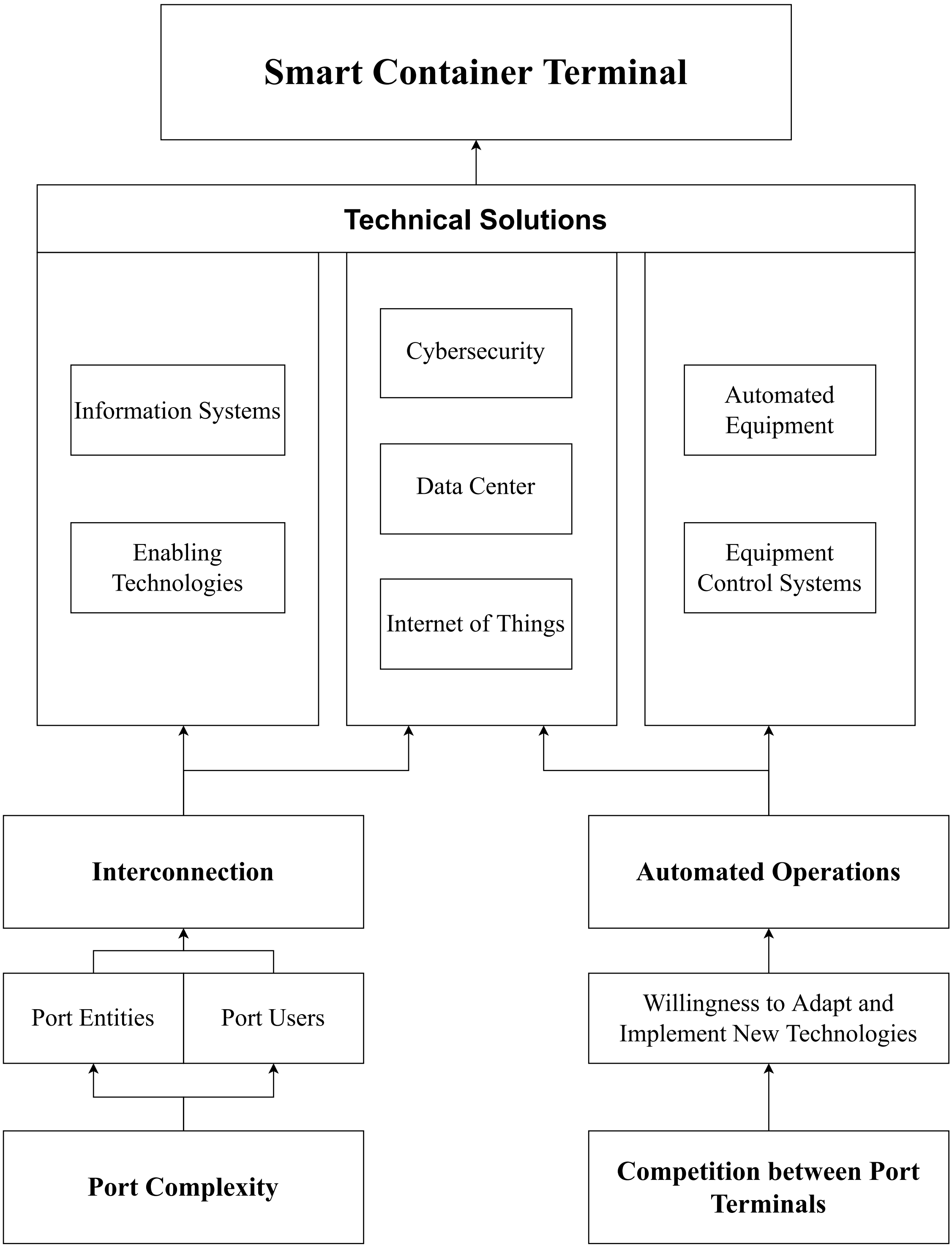

Figure 2.8: Crucial Components and Key Drivers of a Smart Container Terminal

By examining the key components in Figure 2.8, it can be possible to get an idea of the smart port potential (unrealised capabilities or the ability to develop and prepare the port for the future), as this aids to answer RQ1 and RQ2. In this thesis, the model illustrates the main areas that will need to be investigated in the data collection process. In addition, the model will also serve as a template for the structuring the results and discussion chapter.
Technical solutions

Chapter 3

Methodology

This chapter presents the methodical approaches applied in the thesis work. The chapter also covers research design and methods, interview procedures and limitations with the chosen method.

The main approach to answering the research questions has been to first find out how *smart* The Port of Kristiansand is to this date (RQ1). This means getting a holistic view of the implemented smart port elements presented in Figure 2.8 (e.g. automated operations and information systems) in the port. Second, we wanted to find out how the port is facilitated for further integration of such elements (RQ2). This included mapping out potential barriers and possibilities for further implementation of smart port elements, the willingness of the involved parties regarding the use of new technology and/or changes in processes, as well as and enabling technologies. Answering these questions was necessary to answer the problem statement *What is the potential for Port 4.0 in the Port of Kristiansand's container terminal?*, following the definition of potential described in section 1.2. To be able to say anything about *unrealised capabilities*, or *the ability to develop and prepare the port for the future*, it is crucial to answer RQ1 and RQ2. Early in the study it appeared that the Port of Kristiansand had plans to relocate the container terminal to Kongsgård and Vige, and it was therefore interesting to investigate how this will affect the smart port potential (RQ3).

3.0.1 Research Design

From the perspective of Creswell (2013) and Yin (2018), *research design* can be viewed as a blueprint or logical plan that displays *where you are, to where you want to be.* The literature on methodology distinguishes between *qualitative* and *quantitative* research methods, or in some cases, a combination of the two (Patton, 2002).

The qualitative method follows an inductive approach by developing concepts, insights and understanding by acquiring detailed information from a small sample (Leavy, 2017; Taylor et al., 2016). The idea is to not reduce settings and people to values and variables, but view them as whole, while ensuring a close fit between data and people's actions. All perspectives are considered worthy of studying, no matter the hierarchy or roles of the candidates (Taylor et al., 2016).

The quantitative method often follows deductive approaches to the research process and involves measuring parameters and testing relationships, correlations and patterns with the goal of proving, disproving or strengthening existing theories based on a large body of knowledge, such as a statistical overview from a large sample (Leavy, 2017, p. 9).

This study investigated the potential of port 4.0 in the Port of Kristiansand. This problem statement is of the *descriptive* type, and to answer it, one will have to give a descriptive analysis of the current case (Busch, 2019, pp. 32–33). The goal is not to prove or disprove a theory, nor is testing relationships, correlation or patterns, but rather understand and describe the case, based on information from the Port of Kristiansand and the theory explained in the previous chapter. Thus, conducting interviews of the involved parties related to the container terminal was considered as the superior method in terms of data collecting because of the accessibility to first-hand information. Further on, semi-structured interviews would give the opportunity for us to ask additional questions, possibility to change the structure if necessary, or to shed light on other valuable information. Additionally, a substantial amount of the information gathered was not considered necessary to confirm several times. Lastly, by conducting case study research and its complexity, the results can be challenging to quantify. Hence, the research approach is clearly qualitative.

3.0.2 Case Study Research

This thesis is a case study because it takes a closer look at a contemporary phenomenon and how it operates in the real world, as described in Yin (2018). We found that Abercrombie et al. (2006, p. 45)'s definition of a case study is also applicable to our thesis: "... the detailed examination of a single example of a class of phenomena, a case study cannot provide reliable information about the broader class. But it is often useful in the preliminary stages of an investigation since it provides hypotheses which may be tested systematically with a larger number of cases". Whether it is appropriate to conduct a case study mainly depends on two different factors; when the questions call for an extensive and detailed examination of certain social phenomena, and/or the questions explore a contemporary issue (i.e. what causes certain social phenomena) (Yin, 2018).

As mentioned in chapter 2, section 2.2, ports are dissimilar in a variety of aspects. A qualitative, *single case study* with *multiple analysis units* has therefore been chosen to better answer the problem statement of this thesis. In accordance with Johannessen et al. (2016, pp. 203–204), this method is appropriate when the researcher(s) provides a limited context for gathering information about a number of entities.

3.1 Data Collection

3.1.1 Interview

The information gathered through interviews stood for the primary source of data for the thesis. This gave a base for discussing interconnection, automation and technical solutions in the port. The results are based upon the semi-structured, individual and group interviews conducted in conjunction with the *port authorities* (Port of Kristiansand), *port operator* (Seafront) and RedRock.AI, which was acquired by another company and no longer exists. Therefore, RedRock.AI will be referred to as *former RedRock.AI*.

For this study, it was necessary to conduct interviews with the port authorities to answer the problem statement because the respondents were assumed to provide valuable insight in the processes and technologies related to the container terminal. In the selection process of choosing respondents, we were aided by our contact person in the Port of Kristiansand. Preferably we wanted to interview individuals with a varied knowledge base and different positions, mainly on an administrative level. It proved to be difficult to figure out which individuals possessed the relevant knowledge, particularly when it came to having technical knowledge. It was also desirable to interview both port operators as they were assumed to have the most knowledge and technical insight regarding the operations in the container terminal. *Greencarrier*, one of the two port operators in the Port of Kristiansand were contacted, but unfortunately they could not participate and be interviewed due to unfortunate circumstances. Still, an interview was conducted with Seafront. We also chose to interview an employee from an engineering company within marine, offshore, and IT development, formerly known as RedRock.AI. The company was chosen specifically due to the their involvement in a project connected to the container terminal and their competence regarding autonomous vehicles and equipment.

During the interview process, a total of seven respondents participated over a three week period. Generally, we wanted to interview employees with a higher position (management level) to provide a greater overview. Six interviews were conducted (five individual interviews and one group interview with two participants). It should be emphasised that the answers from the individual respondents could have been different if the interview had not been conducted in a group. However, this was not considered a major impact on the data quality because most of the questions did not require subjective perspectives. The duration of the interviews stated in Table 3.1 is a representation of the time from the first to the last question were presented to the respondents. The initial and concluding conversation, as well as the introduction of each interview has therefore been excluded.

Table 3.1: Summary of the Interviews

Interview number	Organisation	Interview type	Duration	Date
1	Port of Kristiansand	Individual	31min	31.03.2022
2	Port of Kristiansand	Individual	36min	01.04.2022
3	Port of Kristiansand	Group	27min	06.04.2022
4	Port of Kristiansand	Individual	29min	11.04.2022
5	Former RedRock.AI	Individual	21min	08.04.2022
6	Seafront	Individual	46min	20.04.2022

The Port of Kristiansand is a Norwegian port, therefore we assumed that Norwegian is spoken by a majority of the employees and management related to the container terminal. We also assumed that by conducting the interviews in Norwegian this would allow the respondents to express themselves more precisely, and that if the respondent had discomfort speaking English, this could prevent the respondent from conveying all of their points and opinions. Therefore, the interviews were conducted in Norwegian.

Documentation of the Interviews

The interviews were documented digitally by using the *record function* in the software communication tool *Zoom*. As for storage of data, this was done locally on PC/MAC, as well as in a shared folder in Microsoft Teams where only we had access.
A written informed consent (i.e. disclaimer) were sent to all of the respondents via e-mail. In addition, the interview questions were sent to all respondents in advance. The written informed consent contained the following information:

- *The interview will be recorded with audio (video is optional).*
- *Transcription and recording of the interview will be deleted by May 20th, 2022.*
- *Your position in the company, as well as company name may be mentioned in this study but personal information will be anonymised.*
- *You are free to end the interview at any time.*

The respondents were also informed of the estimated duration of the interview. The interview's duration differed due to the varying scope of each interview guide.

3.1.2 Interview Guide

The introduction of the interview guide was structured according to the template found in Johannessen et al. (2016, p. 147). The introduction covered general information about topic, the ability to be informed about the results, participant‘s rights and how the interview would be documented.

The general structure of the interview guides was derived from the proposed model (Figure 2.8) to illustrate a smart container terminal. However, the interview guides were tailored to each interview based on our own assumptions regarding the respondents. The respondents would probably not be able to answer all the questions due to the scope of the thesis. For example, the employees in the Port of Kristiansand do not necessarily have as much insight in equipment and technologies related to the process of moving containers as the employees in Seafront. This assumption was made because of the different functions and responsibilities divided between the port operators and the port authority. This information was gathered from our visit to the Port of Kristiansand earlier in 2022. Still, questions that would be answered based on the respondent‘s personal opinions or how they experienced a certain phenomena were asked to a majority of the respondents to get an overall impression. The questions were also formulated in a way that would prevent them from leading the respondents towards an answer. All six interview guides are attached as appendices to this thesis.

One of the challenges of designing the interview guides was to make the questions more comprehensible to individuals who were not familiar with all terms and definitions. To give an example, instead of asking directly about IoT, we asked about the technologies and solutions that make up the concept of IoT. Another issue we faced was to translate established concepts from English to Norwegian. Direct translation of concepts might reduce their meaning, or one might end up with a term that is not as established in Norwegian. Consequently, concepts that are perceived as imprecise can be misleading to the respondents, and might reduce the quality of the answers.

As previously mentioned, the interview guides were sent out in advance. Doing so gave the respondents the opportunity to prepare for the interview, but may also have created unfortunate ripple effects considering questions that required subjective opinions. For example, the respondents being able to discuss the questions with a colleague in advance, and thus, possibly have influenced their initial opinions. Certain questions required subjective opinions or perspectives. Hence, external influence on such opinions might have reduced the quality of the answers.

3.1.3 Transcribing and Data Analysis

All six interviews were transcribed manually with the assistance from transcribing tool in Word Online. As all of the interviews were conducted in Norwegian, they had to be translated and interpreted. During the process of translating the data, words or phrases might have been lost in translation. To combat this issue, the information was carefully analysed and discussed between the authors before and after the translation.

During the transcription process, different words or phrases might have been misinterpreted. To make the transcription more clear, words and phrases that did not contribute to the answer (e.g. filler words), were removed. The quotes that are included in the results section have been translated from Norwegian, and adjusted slightly to better fit with the English language, and provide better fluency. In some cases, we contacted the respondents or our contact person in the Port of Kristiansand if the information appeared to be unclear during the transcription process. It was observed that the recordings from Zoom had some inconsistencies in the volume levels, making it difficult to hear the respondents' answers in certain circumstances. There were also noticed cases of incoherent words. In these cases, incomprehensible words were marked in the transcriptions. To avoid presenting incorrect information, we chose to leave out data that was perceived as instinct when presenting the results.

After the transcription process, the data were analysed and discussed. The data were collected and sorted categorically according to what the respondents stated their response. The categories were based on key elements from Figure 2.8. Only data that were considered relevant to the answering the research questions were presented.

Chapter 4

Empirical Findings and Analysis

In this chapter, we present and discuss the results from the conducted interviews against the findings in the theory chapter. The chapter is categorised after Figure 2.8 to provide a logical structure. A general overview over key aspects like port entities (complexity) information systems, enabling technologies and automated equipment will be provided and discussed. The results themselves will be used to answer RQ1 and map out the degree of smart port elements incorporated in the container terminal. Then, the results will be discussed in order to answer RQ2 and investigate the scope of the further smart port development. Finally, RQ3 will be answered by discussing how relocating the container terminal affects the smart port potential.

4.1 Complexity

In this section, the results related to the complexity of the port is presented and discussed. More complexity means that the development of the smart port concept might be more comprehensive because there are more stakeholders and functions that will have to be interconnected.

The Port of Kristiansand consists of several *port entities* and *port users*. The port authority (Port of Kristiansand) consists of the management and employees in the organisation and owns the port area. Seafront and Greencarrier are the two port operators that handle containers within the container terminal/yard. There are also collaborations with the police, pilotage service provider (Kystverket/The Norwegian Coastal Administration) and customs (Tolletaten/Norwegian Customs Service). As mentioned in (chapter 2, section 2.2), Bichou and Gray (2005, p. 83) implies that different institutions and their roles might overlap, and thus, increase the complexity in the port. In this case, there is an overlap between Seafront's and Greencarrier's function in the port. One way the complexity in the port could be reduced would be to only have one port operator performing the daily container handling operations.

The most important shipping companies related to the port was found to be MSC, ViaSea, Baltic Line, UniFeeder and Maersk. The most prominent carriers/freight forwarding companies were mapped out to be Seafront, Veøy, Vennesla Transport and Landskapsentreprenørene. Other local freight forwarding companies such as MBT, AGA, Pentagon Freight Transport and Bendiks Transport were also mentioned.

4.2 Interconnection

4.2.1 Information systems

Information systems are the key element which enables interconnection in the port, and hence, lays the foundation for the smart port concept. Through our investigations, we discovered that the port authorities employ three information systems; *SafeSeanet*, *Port*, and *PICit*. *SafeSeaNet* is the European Union's Maritime Information and Exchange System used to gather and share detailed maritime information about the situation at sea (European Commission, n.d.). Vessels report to SafeSeaNet, where the information is registered and processed to the *harbour master* in the Port of Kristiansand, so that the port has direct access to relevant details. When a vessel approaches the container terminal they transition to a second information system, *Port*; a port management system developed by Kraken Tools. *Port* provides information regarding the vessels exact location, estimated time of arrival, IMO[1] number, volume of goods and other information related to arrival. We found that *Port* and *SafeSeaNet* contains functions from information systems discussed in the theory chapter. Real-time ship tracking and other key functions from *Vessel traffic services* is provided through *Port*, and several tasks of a PCS, like berth reservation and pre-notifications are supported by both *Port* and *SafeSeaNet*. However, according to the definition of *port community systems* (subsection 2.3.2), all key stakeholders should ideally be connected via electronic systems. Moreover, we determined that there is a degree of overlap between the ICT systems, meaning that several entities have access to similar information, but through different ICT systems. Thus, we consider that the Port of Kristiansand have a degree of PCS, but that it can be further developed. However, the further development of PCS might be extensive and demanding due to challenges related to the integration of ICT systems or other software related issues.

Our respondent from Seafront reported that they are currently using a terminal operating system called *PICit*. Different information can be retrieved from this system, such as which containers are to be loaded onto or unloaded off the ship. The shipping companies transfer relevant information and data by utilising EDI to Seafront‘s systems (PICit). This information is then processed and is accessible to the employees that require it in the container terminal.

Seafront also uses *TimPex*, a *transport management system*, but is about to be replaced by their PICit system. For the purpose of tracking ships and vessels, Seafront uses *Marine Traffic*. The system provides Seafront with information about the location of ships and vessels. It emerged from the results that Greencarrier, the second port operator, uses a different terminal operating system. Seafront and Greencarrier do not have access to each others information systems, and it was was suggested by our respondent from Seafront that sharing one information system could be a possibility. This could reduce the complexity in the port by allowing data flow between the port users, hence simplifying the communication between them.

When asked about *Intelligent Transportation Systems*, the only reported usage was Seafronts real-time tracking of their own trailers. As of today, the Port of Kristiansand does not utilise a *Port road and traffic control system*. Although it could have been useful with such a system to get an overview of the traffic within the port area, the container terminal is a relatively small area with a limited amount of vehicles, and thus, getting an overview of the traffic is uncomplicated. Yet, there is a possibility that utilising a port road and traffic control system could be beneficial in the new container terminal area at Kongsgård and Vige. Still, the need for such a system will be dependant on the amount vehicles moving around the area simultaneously and the size of the terminal area.

The gate to the container terminal consists of two lanes, where one is automated, and the other is operated manually by an employee from Seafront. From the group interview it was

[1] A unique and permanent vessel identification number assigned to individual ships (International Maritime Organization, n.d.).

stated that the automated gate system allows trucks to enter and exit the port automatically. However, this procedure was only available to drivers who had pre-registered their arrival or departure. It turned out that many drivers stopped in the manual lane, and that this could create queuing and ineffectiveness. The gate process would probably be more efficient if both lanes were automated, as this means that trailers can enter or exit the terminal without having to stop for registration. The technology is already in use in the automatic lane, so the potential for implementing it in the manual lane should be high. However, it emerged from some interviews that there had been a few complications with the port users' willingness to adapt when the automated gates were introduced.

There is no *gate appointment system* in use in the Port of Kristiansand, but notifications are given over telephone and e-mail when a container is ready to be picked up. These notifications could be transferred to the freight forwarders with EDI through a system like PICit. For instance, when a container is ready to be picked up, the relevant freight forwarding company receives this information in their systems. Then, the freight forwarding company could book an appointment with Seafront/Greencarrier to pick up the container, and once this appointment is confirmed, the systems (PICit, for instance) communicate the booking information to the gate, which will open automatically as the trailer passes. It was mentioned earlier that the automatic lane only could be used by drivers who had pre-registered their arrival or departure. This pre-registration for using the automatic lane could also be included as a part of the booking process.

"There is a continuous adaptation and merging of systems, because we operate many different systems. We want to reduce the number of systems and gather more together." - Respondent, Seafront

We found that e-mail, telephone and VHF[2] systems were the most common means of communication between port entities. The respondents from the port authorities assessed the communication flow between them and the shipping companies/freight forwarders as satisfactory. However, it was mentioned by some respondents that it could be improved. Both the port authorities and Seafront answered that the communication flow between them was satisfactory. However, it was also mentioned by some respondents that it could be better, and that there is a lot to gain from digitalisation. Seafront reports that the communication between them and the port users is good, but that they wish to obtain information faster.

After analysing the results, no PHIIS (Port Hinterland Intermodal Information System) was discovered. Lastly, *Automated yard systems* were not found during this study, but these systems are more relevant as soon as automation in the container terminal takes effect.

4.2.2 Enabling Technologies

Table 2.2 presented different enabling technologies that facilitate interconnection. Table 4.1 sums up the enabling technologies that are being used in conjunction with the container terminal.

[2] Very high frequency radio waves used for communication.

Table 4.1: Enabling Technologies utilised in conjuction with the container terminal

Enabling Technology	Application in the Port of Kristiansand
GPS / DGPS	GPS / DGPS is not currently in use in relation to the container terminal in The Port of Kristiansand.
Electronic data interchange (EDI)	Communication in PICit, SafeSeaNet and Port are carried out through EDI. However, certain reports and documents are still in paper format.
Radio-frequency identification (RFID)	Seafront utilises RFID on their trucks to locate them at all times.
Optical character recognition systems (OCR)	An ongoing project, but no usage of this technology was documented.
Real-time location systems	AIS (Automatic Identification System) ensures live tracking of ships. Seafront has live tracking of their trucks.
Wireless sensor networks	There are no sensor networks or sensors in use in the container terminal.
Mobile Devices	Mobile devices are used by those who are involved in the container handling operations (e.g. reach-stacker drivers)
Wireless Network	The port has several wireless networks, but as noted by the respondent from Seafront, the signal is not stable enough for systems to rely on, so the mobile devices use 4G network. Respondents from the port authorities stated that the wireless network is of a satisfactory standard. Seafront explained that they are planning on utilising 5G technology when it becomes available. This was also mentioned by one respondent from the port authorities.

GPS or DGPS are not used in the container terminal as of today. However, this technology could become more appropriate when the need for tracking vehicles in the terminal increases. This need may appear when vehicles are autonomous, or for port road and traffic control systems.

As shown in Table 4.1, the use of EDI is present, but certain reports and documents are hand written. Thus, there is still a potential for improvement in this area. More reports and processes could possibly be integrated in the terminal operating system to increase the information exchanged through EDI. One of the respondents acknowledged that a potential barrier for this development could be the willingness of the employees, and to some to some extent, the technical capabilities of those who handle these reports.

As of today, camera technology is used when trucks enter and exit of the container terminal. Pictures are taken of the container and the truck to document any damage at entry and exit that the driver has not previously detected. An *OCR-system* could be implemented to automatically register the container number in this case. It is also a possibility to use OCR for automatic damage inspection of the container, as mentioned in Table 2.2. Further, OCR could be used to read the licence plate on the truck to automatically register which truck transports the container through the gate. If this system communicated with PICit, the overview of the container flow in and out of the terminal could increase. This is due to the added information that would be handled by PICit. Additionally, the manual work regarding checking for damage on containers could be avoided, and photographs of the containers could be sorted in PICit. It was mentioned that Seafront had an ongoing project regarding OCR on their reach stackers to avoid manual input of container numbers. It is much possible that the same OCR-system could be used in the gates with minor adjustments.

4.3 Competition between Port Terminals

"We believe that more goods should be transported by sea and it is an overriding national goal also that more goods should go by sea and railway, and away from the road"
- Respondent, Port Authorities

There was a unanimous answer from the respondents saying that there is no competition between the Port of Kristiansand and other ports. Further, the port market in Norway was illustrated by two of the respondents as a line with natural stops, where the Port of Kristiansand is a part of this line. Interestingly, one respondent from the port authorities even stated that more traffic generated in nearby ports will generate more traffic in the Port of Kristiansand. As the Port of Kristiansand and the majority of the other Norwegian ports are publicly owned, could be one reason why the level of competition is non-existent. Our results also indicate that the establishment of new ports (Threat of new entrants, subsection 2.4.1) is not viewed as a threat. Because of this, *Rivalry among existing competitors*, *Threat of new entrants* and *Rivalry among existing competitors* are not considered drivers for smart port development in the port of Kristiansand.

The majority of the respondent said that they had an adequate overview of digitalisation and innovation processes in other ports. Interestingly, this mostly came from cooperation and information sharing with other ports in an organisation called *Norske Havner*, where participants from different ports in Norway can share their experiences. From the results we found that an example of such collaboration between ports was the project *KystTerminal*, which was completed in 2019. The project's purpose and objective was to develop the future coastal terminals for containers with future-oriented infrastructure, including necessary area, quays, equipment, handling equipment, power connection, IT and other facilities. Additionally, we discovered that projects had been executed in cooperation with other ports in Europe. These findings suggest that cooperation between ports is a driver for smart port , and not competition between ports. The more technological solutions, innovations and projects that ports share among each other, the more the potential for smart port development increase.

After analysing data related to the competitive situation, we also found that it was a consistent response from three of the respondents from the port authorities that land transport (Threat of substitute products or services, subsection 2.4.1) was a direct competitor to the Port of Kristiansand. Two respondents from the port authorities stated that transporting goods by sea is normally a more complex way of transport due to the additional steps of loading and unloading procedures. For sea transport to compete with land transportation, it must be more appealing to customers, who in this case is the person/company who owns the goods that are being shipped. A solution could be to make the process of transporting goods by sea (short-sea shipping) more efficient, affordable and intuitive to the customers. Competing with land transportation could lead to accelerating the development of the smart port concept, and thus, act as a driver for such development.

With reference to industry exposure to de/regulative activities (subsection 2.4.2), respondents from the port authorities and Seafront were asked how new/changing municipal and/or state rules and regulations affect the Port of Kristiansand, along with if rules and regulations limit the efficiency of the port. In our analysis, we found that there are favourable regulations for port operations, and that the overall efficiency in the Port of Kristiansand is not restricted.

For us, there is always one thing that comes first, and that is safety, and laws and regulations help us with that because it ensures that the actors around us must follow it. - Respondent, Port authorities

"Laws and regulations does not limit our port activities, but the physical location of the port does." - Respondent, Seafront

"State regulations does not affect us, but that politicians could have an impact, especially regarding the relocation aspect." - Respondent, Port authorities

Favourable regulations and no significant restrictions allow for innovation to take place within the port (container terminal), as well as giving room to implement new solutions or technologies without any obstacles. This is also mentioned by Isabelle et al. (2020, p. 36). Thus, the potential for the smart port concept in the Port of Kristiansand can be considered as higher.

4.4 Automated Operations

As of today, the process of handling containers are done manually. The process of handling containers in the container terminal begins when a vessel has been moored. Then, the cranes (Figure 4.2) operated by the port authorities lift the containers ashore. Seafront's role during this process is loading and unloading procedures of containers. This is done by manned reach stackers, which are vehicles that lift and move the containers within the terminal area. An illustration of one of the reach stackers in the Port of Kristiansand is provided in Figure 4.1.

Figure 4.1: Manned Reach Stacker in the Port of Kristiansand (Port of Kristiansand, n.d.-a)

After the crane places the container on the ground, one of the reach stackers picks it up and places it in a dedicated area within the terminal for storage. When the time has come for further transportation, a reach stacker picks up the container from the storage area, and places it on a truck. The process is reversed for containers that enter the port via trucks. This means that there are no autonomous vehicles or equipment (e.g automated mooring system, AGVs or AYCs) in the container terminal with the exception of the automated gate system discussed in subsection 4.2.1. Our respondent from Seafront states that the volume of goods (i.e. throughput) in the container terminal is too low to invest in autonomous technology (e.g. autonomous reach stackers), and consequently it can not be justified from a profitability perspective to invest in this type of technology. It was also mentioned that by moving to a new location, this type of investment may become more profitable in the long run. However, there are ongoing projects related to autonomy, for instance, former RedRock.AI were participating in one of project, where the goal was to autonomously transport processed nickel cargo from a truck to a container. Seafront's respondent further elaborated that: "We can envisage doing one - or two maybe - of what we call departments at our terminal, autonomous during 2022 and 2023". Also, according to Seafront's respondent, the company is constantly looking for ways to simplify and automate their operations. In conclusion, there are clear signs that the willingness and motivation to implement new technologies and solutions is present in Seafront. We have considered willingness as an important factor when assessing the smart port potential section 2.4.

Currently, the cranes (quay cranes) in the Port of Kristiansand are not autonomous. The respondent from former RedRock.AI explained that they have the ability to digitalise most existing vehicles and adds that older vehicles takes more effort to digitalise and make autonomous. To digitalise vehicles and equipment, former RedRock.AI utilises a digital system (equipment-control systems) in combination with specialised sensor technology that are tailored to the current equipment. A selection of the cranes in the harbour already have control systems, or are digitalised to some degree. This provides more opportunity for remote control of the cranes and automation. This means that the main barrier to automating the cranes in the port is mostly related to administrative paperwork as elaborated by former RedRock.AI´s respondent, hence providing a greater potential for automating the equipment in the container terminal.

"There is an enormous potential out there. They just have to accept it and see the value in it."

- Respondent, former RedRock.AI

During our literature review, research regarding *autonomous reach stackers* was not found. In an automated container terminal, a simple setup of AGVs, AQCs and AYCs would replace the need for autonomous reach stackers (subsection 2.5.1). Currently, we consider that the physical area is too small and that the layout is disadvantageous at Lagmannsholmen to fully take advantage of such a setup. This is because the automated vehicles and equipment illustrated in subsection 2.5.1 are dependent on a rectangular area. When relocating to the Kongsgård and Vige area, we suggest that in the long term, the Port of Kristiansand should consider the setup shown in Figure 2.7 as a starting point when planning for an automated container terminal.

The respondent from Seafront reports that the greatest barrier towards automation and digitalisation of the container terminal/port is the lack of available technology. Additionally, costs were cited as another barrier. Our results also show that Seafront is involved in projects that focuses on developing technology for the container terminal to combat this issue.

As elaborated in (Table 4.1), the WiFi network in the container terminal is of low quality. For this reason, the tablets are equipped with 4G technology and avoids using the WiFi network. This creates a barrier for the smart port development because a majority of the equipment used in smart ports will be reliant on a stable and fast wireless network (subsection 2.5.4). Furthermore, 5G technology is not available in Kristiansand at the time of writing this thesis, so upgrading the WiFi in the container terminal, or waiting for the 5G establishment are the only true options for removing this barrier. As mentioned in Table 4.1, the use of sensors or sensor networks in the container terminal was not discovered. In addition, no actuating devices that were connected to a wireless network were found. We also did not find that any machinery, vehicles or other equipment were connected to the internet or any other type of network. The need for a fast and reliable wireless network is significantly lower as none of these technologies were found. However, once the Port of Kristiansand decides to incorporate IoT technology, this need will increase drastically. Relocating the container terminal to the Kongsgård and Vige area gives the the port the opportunity to optimise and plan for the implementation of IoT.

4.4.1 Data Center and Cybersecurity

According to our research, the Port of Kristiansand does not have a dedicated data center. Instead, the information and data is stored by the Municipality of Krisitiansand. For data storage, Seafront stores their information in the terminal operating system (PICit). With respect to cybersecurity, the Municipality of Kristiansand are responsible for handling this matter for the port. Nonetheless, the respondent from Seafront specified that they had outsourced this type of service to a third-party company with whom they have had a long-term and trust-based collaboration. The respondent from former RedRock.AI also explained that to ensure and maintain their cybersecurity measures, advanced protocols were being used. If the Port of Kristiansand implements IoT features and technology into their daily operations, the need for their own data center that can handle and store a greater amount of digital information might arise. Connecting more machinery and equipment to a network also adds to the overall vulnerability regarding cyberattacks (e.g. hacking). The respondent from former RedRock.AI elaborated that when dealing with heavy machinery (e.g. an 80 tonne reach stacker loaded with a full container) in the container terminal, it is crucial that one have complete control over the machine, as significant damage to humans, goods or infrastructure could take place if proper cybersecurity measures has not been established. Thus, additional focus on cybersecurity will be required as the port gets more digitalised.

4.5 Relocation of the Container Terminal

Our results show that the Port of Kristiansand has been given permission to move the container terminal as this is an approved municipal sub-plan. Most of the Kongsgård and Vige area is not in use, and our study shows that there are substantial opportunities to plan to expand the container terminal for optimal operation. Findings related to how the relocation will affect the smart port potential are listed and presented below under each sub-topic.

Physical area

Based on our findings, the most prominent benefit of relocating the container terminal is related to the increase in physical area compared to the current area at Lagmannsholmen. Our research shows that Lagmannsholmen has an unfavourable container terminal area because the size and layout makes it complicated to perform container handling operations. Also, a u-shaped *quay area* (Figure 4.2) makes efficient operations challenging because vessels must be moored on either side of the quay.

Figure 4.2: An Overview of the U-shaped Quay at Lagmannsholmen (Port of Kristiansand, n.d.-a)

Having a larger and more rectangular terminal area with a *single quayside* is therefore considered as a superior solution. By accommodating one quayside and having all the terminal operations behind the quay will facilitate more *operational efficiency*, and thereby unnecessary driving around the quay area can be avoided.

Safety

Our respondent from Seafront reported that safety is a concern in Lagmannsholmen due to traffic at both sides of the container terminal. It was further explained that by relocating to a larger area, and thereby providing Seafront with *their own area* could enhance the safety aspect.

Key infrastructure

As of today, the Kongsgård and Vige area has various infrastructure in place, but certain development is required. The surrounding infrastructure (e.g. road and quay) is to some degree in place. Connection between the port and the hinterland is emphasised in literature regarding the smart port concept. Lagmannsholmen has connection to the hinterland via

European route E18. Upon moving to the Kongsgård and Vige area, the same connection can be maintained and consequently this will not affect the potential for smart port in a negative way. Moreover, the results show that it is not necessary to develop or expand the existing road infrastructure, even if the capacity of the container terminal expands. As for the quay infrastructure, several respondents from the port authorities stated that they partially have the quay infrastructure in place. However, they are building and extending the quayside further to ensure that two vessels can be moored after one another. When considering the smart port concept, an extended quayside in conjunction with a rectangular area behind the quay (Figure 2.7) is viewed as the superior solution as it enables for more efficient operations.

Chapter 5

Conclusion

This thesis has attempted to fill a research gap related to the smart port development of smaller ports in Norway. This was done by collecting literature and applying it to a Norwegian port. Hence, the results contribute with new perspectives to the current literature. In addition, this thesis work acts as a proposal for the further development of the Port of Kristiansand. The three research questions below attempts to answer the problem statement:

What is the potential for Port 4.0 in the Port of Kristiansand's container terminal?

RQ1. *To what extent are smart port elements integrated in the container terminal?*

We found that several enabling technologies (e.g. mobile devices and EDI) and information systems (e.g. TOS) were used for day-to-day operations in the container terminal. Yet, there were also information systems from the literature that were not identified. Interestingly, we discovered a technology called AIS (Automatic Identification System), which is used for real-time vessel tracking and that replaced the need for GPS and RFID-tracking of vessels. The WiFi network in the container terminal was evaluated as of low quality, and was considered a barrier for implementing IoT. Consequently, no vehicles or equipment were connected to a network. Furthermore, the only daily operation that was automated was the gate system. The gate system consisted of two lanes, but only one is automated. We also identified that the equipment in the container terminal differed from what was described in the literature. The container handling operations in the terminal differed from what we found in the literature. Automated equipment such as AYCs, AQCs and AGVs were replaced by manned reach stackers and mobile quay cranes (Figure 4.2). Moreover, we established that the Port of Kristiansand does not have their own data center but is managed by the Municipality of Kristiansand and other third-party companies. This is also applicable for the cybersecurity measures.

Lastly, individual automation of port operations exists, and the port entities have implemented their own information systems (e.g. *PICit* and *Port*). In addition, we have discovered that the willingness to adapt and implement new technologies is present with the port authorities and the port operator (Seafront). Hence, according to the five stages towards a smart port status (Table 2.1), we consider that the Port of Kristiansand's container terminal is at stage 1 (*monitor port*).

RQ2. *How extensive is the further development of smart port in the container terminal?*

The scope of the further development of the smart port concept will be reduced if the complexity of the port is reduced. Therefore, we propose that only *one* port operator is used by the Port of Kristiansand, or that the two port operators (Seafront and GreenCarrier) currently cooperating the container terminal share one information system.

There are opportunities associated with the *automated gate system* as this can be expanded to include *gate appointments* through a common platform, such as PICit. We establish that the gate system‘s manual lane could be converted into an automated lane without much effort. There is also potential in developing OCR technology to streamline operations and additional operations could be included in PICit (or other information systems) to increase the degree of EDI in the container terminal. Further development of PCS can be considered beneficial, but might be extensive due to the integration of numerous different systems.

As our findings suggest, competition between ports was identified as a driver for the smart port development in Norway. However, we instead discovered that the Port of Kristiansand cooperates with other ports in Norway and Europe. This combined effort is considered to increase the smart port potential as technological solutions, innovations and projects are shared between ports. Further, we recognised that competition with land transportation was present in the Port of Kristiansand. In order to maintain a competitive advantage, the Port of Kristiansand must make their services more efficient, affordable and intuitive for customers through innovation. The willingness to compete with land transportation was observed among the employees in the Port of Kristiansand. This willingness can be seen as a step towards further development.

Moreover, we learned that there are opportunities related to automating the current equipment in the container terminal. Still, due to the unfavourable size and layout of the terminal, automating different processes and equipment might prove to be challenging. We also learned that Seafront has ongoing projects regarding automation in collaboration with other engineering companies (e.g. former RedRock.AI). In this area we also discovered willingness to adapt and implement new technologies in Seafront, which is an important step forward. Combining this with favourable rules and regulations, we consider that a solid foundation for innovation is established. Additionally, when 5G is established in Kristiansand, the potential for IoT and interconnection will increase. Until then, it is necessary to upgrade the wireless network in the container terminal to maintain the same capabilities.

If additional technical solutions are implemented, and more devices, systems and equipment are to connected to a network, the need for cybersecurity increase. This may therefore be something the port should look into in the long run. With the further development of information systems and technical solutions, the amount of data being handled will increase. For that reason, a dedicated data center may become necessary.

To summarise, the scope of the further smart port development in the Port of Kristiansand is significant. However, in total, there are many technical areas that can be improved today. Furthermore, there is technology in the port that can be both upgraded and expanded to serve more purposes. As such, The Port of Kristiansand have adequate opportunities to make incremental upgrades to their information systems. Furthermore, there are things that can be done to reduce the overall scope. Finally, there is a general willingness in the Port of Kristiansand to be competitive and innovate, which provides a good starting point for further implementing smart port elements.

RQ3. *How will the relocation of the container terminal impact the smart port potential?*

Relocating the container terminal at Lagmannsholmen to the Kongsård and Vige will provide an area that is more convenient for container handling operations. We also determine that there are substantial opportunities to make the port smart, or to facilitate future smart port development. We also observed that by relocating, the Port of Kristiansand do not miss out on any opportunities and will not negatively impact the day-to-day operations. In conclusion, our findings indicate that relocating the container terminal from Lagmannsholmen to the Kongsgård and Vige area greatly enhances the smart port potential.

5.1 Generalisation

Ports are as described in section 2.3 dissimilar in the way they function and operate which might reduce the possible generalisation of the results of this study. The results may be less transferable to ports that are at a different stage in the smart port development. Nonetheless, the results may provide useful information to other ports similar to the Port of Kristiansand. Moreover, many factors can influence the results in this case study, such as laws and regulations, and competitive aspects, ownership model, making it difficult to determine whether if the results can be generalised for international ports. However, the approach and the model utilised in this thesis can be used to investigate the implementation of smart port elements and evaluate the scope of further smart port development in other ports.

5.2 Limitations and Recommendations for Future Research

Due to the limitations of the thesis, other interesting areas of research have not been investigated. Available capital is an important component in the development of a smart port. Therefore, the next step could be to analyse the costs associated with the smart port concept. It could also be of interest to map out the possible consequences related to profitability, efficiency, safety or sustainability of turning the container terminal of the Port of Kristiansand into a smart port. Another suggestion for future research is to investigate the throughput (volume of goods) required for it to be profitable to automate the container terminal. Finally, it could be of interest to utilise our model (Figure 2.8) to find the smart port potential in a different terminal (e.g. ferry terminal or offshore terminal).

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Appendix A

Interview Guide - Port Authorities

Generelt

- Er du kjent med begrepene *Smarthavn/Smart Port/Port 4.0*?

Kompleksitet

Havneorganisasjoner

*Hensikten med denne seksjonen er å kartlegge omfanget av organisasjoner og interessenter som er relatert til containerterminalen og dens logistikkjede.

- Kan du gi oss en oversikt over havneoperatører, bedrifter og organisasjoner som arbeider i forbindelse med containerterminalen?
- Er det noen andre involverte parter?
- Kan du beskrive havneanløpsprosessen?

Havnebrukere

- Hvilke rederier bruker havnen?
- Hvem er transportørene/spedisjonsbedriftene?

Havne- og terminalmarkedet

Hensikten med denne seksjonen er å kartlegge konkurransen mellom Kristiansand Havn og andre havner.

- Er Kristiansand Havn konkurransedyktig i forhold til andre havner? Hvorfor/hvorfor ikke?
- Er det noen tjenester som Kristiansand Havn tilbyr som ikke tilbys i andre havner? Hvilke?
- Har du oversikt over digitaliserings- og innovasjonsprosesser i konkurrende havner?
- Opplever Kristiansand Havn konkurranse fra landtransportselskaper? På hvilken måte?
- Hvordan påvirkes Kristiansand Havn av nye/endrende kommunale -og statlige regler og forskrifter? I så fall, begrenser dette effektiviteten i havnen?
- Anses utbygging av nye havner som en trussel for Kristiansand Havn?

Automasjon

Hensikten med denne seksjonen er å kartlegge automasjon i forbindelse med containerterminalen.

- Hvilke automatiserte prosesser anvender Kristiansand Havn i dag?
- Kan de nye kranene i containerterminalen styres trådløst/eksternt?
- Er det mulig å helautomatisere de nye kranene?

Kommunikasjon og informasjonsflyt

Hensikten med denne seksjonen er å kartlegge informasjonsflyt og kommunikasjon mellom havnebrukere, havneorganisasjoner og havneoperatører i forbindelse med containerterminalen.

- Hvordan vil du vurdere kommunikasjonen og informasjonsflyten mellom havnebrukere, havneorganisasjoner og havneoperatører?
- Hvordan vil du beskrive kommunikasjonen og informasjonsflyten med havneoperatører?
- Anvender aktører i Kristiansand Havn (havneoperatører, havnebrukere etc.) ulike informasjonssystemer?
- Muliggjørende teknologier (teknologier som legger til rette for moderne løsninger og systemer)
  - Hvordan er rekkevidden, hastigheten, stabiliteten og tilgjengeligheten på WiFi-nettverket?
  - Hvilke systemer anvender Kristiansand Havn for å spore skip?
  - Benytter Kristiansand Havn elektronisk datautveksling (EDI - Electronic Data Interchange)? Unngås bruken av håndskrevne dokumenter? I hvilken grad?
- Har Kristiansand Havn tilgang til havneoperatørenes digitale informasjonssystemer eller informasjon som inngår i disse systemene?
- Har Kristiansand Havn et datasenter per dags dato? Hva brukes det til? Hvem har tilgang?
- Hvilke tiltak gjøres det for å opprettholde cybersikkerheten?

Bærekraftig energiforbruk

Hensikten med denne seksjonen er å danne et overordnet bilde av energiforbruk knyttet til containerterminalen.

- Hvor lang er vanligvis ventetiden til skip under havneanløpsprosessen?
- Er det andre flaskehalser som kan forårsake for eksempel utslipp? (Fra skipet ankommer havnen, til containeren forlater havnen).

Flytting av containerterminalen

Hensikten med denne seksjonen er å få et bedre bilde av flytteprosessen av containerterminalen til Kongsgård/Vige-området.

- Hvilke fordeler ser du ved å flytte containerterminalen til Kongsgård/Vige-området?
- Er det noen ulemper ved å flytte?
- Hva er budsjettet?
- Hvis dere får grønt lys til å begynne flytteprosessen av containerterminalen, hvor langt tid vil dette ta?

Avslutningsspørsmål

- Hvordan vil du beskrive omstillingsevnen til de ansatte i Kristiansand Havn?
- Er det noe vi ikke har snakket om, men burde ha snakket om?
- Andre ting som vi burde ha tatt opp til diskusjon?

Appendix B

Interview Guide - Port Authorities

Generelt

- Er du kjent med begrepene *Smarthavn/Smart Port/Port 4.0*?
- Hvordan opplever du havnebrukernes villighet til å tilpasse seg endrede prosesser i havnen?

Havne -og terminalmarkedet

Hensikten med denne seksjonen er å kartlegge konkurransen mellom Kristiansand Havn og andre havner.

- Er Kristiansand Havn konkurransedyktig i forhold til andre havner? Hvorfor/hvorfor ikke?
- Er det noen tjenester som Kristiansand Havn tilbyr som ikke tilbys i andre havner? Hvilke?
- Har du oversikt over digitaliserings- og innovasjonsprosesser i konkurrende havner?
- Opplever Kristiansand Havn konkurranse fra landtransportselskaper? På hvilken måte?
- Hvordan påvirkes Kristiansand Havn av nye/endrende kommunale- og statlige regler og forskrifter? Begrenser dette effektiviteten i havnen?
- Anses utbygging av nye havner som en trussel for Kristiansand Havn?

Kommunikasjon og informasjonsflyt

Hensikten med denne seksjonen er å kartlegge kommunikasjon og informasjonsflyt kommunikasjon mellom havnebrukere, havneorganisasjoner og havneoperatører i forbindelse med containerterminalen.

- Hvordan vil du vurdere kommunikasjonen og informasjonsflyten mellom havnebrukere, havneorganisasjoner og havneoperatører?
- Hvordan vil du vurdere kommunikasjonen og informasjonsflyten i Kristiansand Havn?

Flytting av containerterminalen

Hensikten med denne seksjonen er å få et bedre bilde av flytteprosessen av containerterminalen til Kongsgård/Vige-området.

- Hvilke fordeler ser du ved å flytte containerterminalen til Kongsgård/Vige-området?
- Er det noen ulemper ved å flytte?
- Hva er budsjettet for dette prosjektet?
- Hvis dere får grønt lys til å begynne flytteprosessen av containerterminalen, hvor langt tid vil dette ta?
- Har Kristiansand Havn utarbeidet planer angående utbygging av infrastrukturen rundt Kongsgård/Vige-området?
  - Vil det være behov for utarbeiding av ny vei?
  - Vil det være behov for utarbeiding av jernbane?
  - Vil det være behov for å bygge ut annen infrastruktur?

Avslutningsspørsmål

- Hvordan vil du beskrive omstillingsevnen til de ansatte i Kristiansand Havn?
- Er det noe vi ikke har snakket om, men burde ha snakket om?

Appendix C

Interview Guide - Port Authorities

Generelt

- Er dere kjent med begrepene *Smarthavn/Smart Port/Port 4.0*?
  - I hvilken grad er Kristiansands Havn en sånn?
  - Hva må til for å bli en?

Havne- og terminalmarkedet

Hensikten med denne seksjonen er å kartlegge konkurransen mellom Kristiansand Havn og andre havner.

- Er Kristiansand Havn konkurransedyktig i forhold til andre havner? Hvorfor/hvorfor ikke?
- Er det noen tjenester som Kristiansand Havn tilbyr som ikke tilbys i andre havner? Hvilke?
- Har dere oversikt over digitaliserings- og innovasjonsprosesser i konkurrende havner?
- Opplever Kristiansand Havn konkurranse fra landtransportselskaper? På hvilken måte?
- Hvordan påvirkes Kristiansand Havn av nye/endrende kommunale- og statlige regler og forskrifter? Begrenser dette effektiviteten i havnen?
- Anses utbygging av nye havner som en trussel for Kristiansand Havn?

Automasjon

Hensikten med denne seksjonen er å kartlegge automasjon i forbindelse med containerterminalen.

- Anvender Kristiansand Havn automatisert utstyr/maskiner per i dag? Hvilke?
- Kan de nye kranene i containerterminalen styres trådløst/eksternt?
  - Er det mulig å helautomatisere de nye kranene slik som de er nå?
- Er det mulig å helautomatisere havnetruckene i havnen?

Kommunikasjon og informasjonsflyt

Hensikten med denne seksjonen er å kartlegge informasjonsflyt og kommunikasjon mellom havnebrukere, havneorganisasjoner og havneoperatører i forbindelse med containerterminalen.

- Anvendes det idag systemer for å avtale levering/henting av containere med lastebil?
  - Anvendes det idag systemer for å få oversikt over skipstrafikken?
  - Hvilken informasjon kan man hente ut fra slike systemer?
  - Hvordan teknologi brukes i disse systemene? (Radarsystemer, radiokommunikasjonssystemer, sanntidssystemer for lokalisering, video-overvåkningssystemer etc).
  - Hvilke systemer anvender Kristiansand Havn for å spore skip?
- Benytter Kristiansand Havn systemer som informerer om trafikken i nærområdet?
- Hvordan vil dere vurdere kommunikasjonen og informasjonsflyten mellom Kristiansand Havn, havnebrukere (rederier, transportører etc) og havneoperatører (Seafront og Greencarrier)?
- Anvender aktører i Kristiansand Havn (havneoperatører, havnebrukere etc) ulike informasjonssystemer?
- Hvordan er rekkevidden, hastigheten, stabiliteten og tilgjengeligheten på WiFi-nettverket?
  - Hvor mange WiFi-nettverk har dere i havnen?
- Benytter Kristiansand Havn elektronisk datautveksling (EDI - Electronic Data Interchange)? Unngås bruken av håndskrevne dokumenter? I hvilken grad?
- Har Kristiansand Havn tilgang til havneoperatørenes digitale informasjonssystemer eller informasjon som inngår i disse systemene?
- Har Kristiansand Havn et datasenter per dags dato? Hva brukes det til? Hvem har tilgang?
- Hvilke tiltak gjøres det for å opprettholde cybersikkerheten?

Bærekraftig energiforbruk

Hensikten med denne seksjonen er å danne et overordnet bilde av energiforbruk knyttet til containerterminalen.

- Hvor lang er vanligvis ventetiden til skip under havneanløpsprosessen?
- Er det andre flaskehalser som kan forårsake utslipp? (Fra containeren ankommer havnen, til containeren forlater havnen).

Flytting av containerterminalen

Hensikten med denne seksjonen er å få et bedre bilde av flytteprosessen av containerterminalen til Kongsgård/Vige-området.

- Hvilke fordeler ser dere ved å flytte containerterminalen til Kongsgård/Vige-området?
- Er det noen ulemper ved å flytte?

- Hva er budsjettet for dette prosjektet?
- Hvis Kristiansand Havn får grønt lys til å begynne flytteprosessen av containerterminalen, hvor langt tid vil dette ta?
- Har Kristiansand Havn utarbeidet planer angående utbygging av infrastrukturen rundt Kongsgård/Vige-området (El-kraftnett, vei etc)?

Avslutningsspørsmål

- Hvordan vil dere beskrive omstillingsevnen i forhold til ny teknologi og/eller endringer i prosesser hos de ansatte i Kristiansand Havn?
- Hvordan vil dere beskrive omstillingsevnen i forhold til ny teknologi og/eller endringer i prosesser hos havnebrukere (transportører og rederier)?
- Er det noe vi ikke har snakket om, men burde ha snakket om?

Appendix D

Interview Guide - Port Authorities

Generelt

- Er du kjent med begrepene *Smarthavn/Smart Port/Port 4.0*?
  - I hvilken grad er Kristiansands Havn en sånn?
  - Hva må til for å bli en?
- Hvilke landtransportselskaper henter/leverer containere?
- Hvilke rederier benytter havnen?

Havne- og terminalmarkedet

Hensikten med denne seksjonen er å kartlegge konkurransen mellom Kristiansand Havn og andre havner.

- Er Kristiansand Havn konkurransedyktig i forhold til andre havner? Hvorfor/hvorfor ikke?
- Er det noen tjenester som Kristiansand Havn tilbyr som ikke tilbys i andre havner? Hvilke?
- Har du oversikt over digitaliserings- og innovasjonsprosesser i konkurrende havner?
- Opplever Kristiansand Havn konkurranse fra landtransportselskaper? På hvilken måte?
- Hvordan påvirkes Kristiansand Havn av nye/endrende kommunale- og statlige regler og forskrifter? Begrenser dette effektiviteten i havnen?
- Anses utbygging av nye havner som en trussel for Kristiansand Havn?

Automasjon/automatiserte prosesser

Hensikten med denne seksjonen er å kartlegge automasjon i forbindelse med containerterminalen.

- Anvender Kristiansand Havn automatisert utstyr/maskiner per i dag? Hvilke?
  - Er det andre automatiserte prosesser som anvendes?
- Kan de nye kranene i containerterminalen styres trådløst/eksternt?

  - Er det mulig å helautomatisere de nye kranene slik som de er nå?
  - Hva heter de nye kranene (merke/type/modell)?

- Er det mulig å helautomatisere havnetruckene i havnen?

Kommunikasjon og informasjonsflyt

Hensikten med denne seksjonen er å kartlegge informasjonsflyt og kommunikasjon mellom havnebrukere, havneorganisasjoner og havneoperatører i forbindelse med containerterminalen.

- Benyttes det sensorteknologi i områder tilknyttet containerterminalen?
- Benyttes det GPS-teknologi i områder tilknyttet containerterminalen?
- Anvendes det idag systemer for å avtale levering/henting av containere med lastebil?
  - Avtales det tidspunkt ved registrering?
- Anvendes det idag systemer for å få oversikt over skipstrafikken?
  - Hvilken informasjon kan man hente ut fra slike systemer?
  - Hvordan teknologi brukes i disse systemene? (Radarsystemer, radiokommunikasjonssystemer, video-overvåkningssystemer etc).
  - Hvilke teknologi anvender Kristiansand Havn for å spore skip?
- Benytter Kristiansand Havn systemer som informerer om landtrafikken i nærområdet?
- Hvordan vil du vurdere kommunikasjonen og informasjonsflyten mellom Kristiansand Havn, havnebrukere (rederier, transportører etc) og havneoperatører (Seafront og Greencarrier)?
- Anvender aktører i Kristiansand Havn (havneoperatører, havnebrukere etc) ulike informasjonssystemer?
- Hvordan er rekkevidden, hastigheten, stabiliteten og tilgjengeligheten på WiFi-nettverket?
  - Hvor mange WiFi-nettverk har du i havnen?
  - Har Kristiansand Havn planer om å anvende 5G-teknologi når det blir tilgjengelig?
- Benytter Kristiansand Havn elektronisk datautveksling (EDI - Electronic Data Interchange)? Unngås bruken av håndskrevne dokumenter? I hvilken grad?
- Benyttes det mobile enheter i forbindelse med informasjonssystemer (tablets, annet håndholdt utstyr etc)?
- Har Kristiansand Havn tilgang til havneoperatørenes digitale informasjonssystemer eller informasjon som inngår i disse systemene?
- Har Kristiansand Havn et datasenter per dags dato? Hva brukes det til? Hvem har tilgang?
- Hvilke tiltak gjøres det for å opprettholde cybersikkerheten?

Bærekraftig energiforbruk

Hensikten med denne seksjonen er å danne et overordnet bilde av energiforbruk knyttet til containerterminalen.

- Hvor lang er vanligvis ventetiden til skip under havneanløpsprosessen?
- Er det andre flaskehalser som kan forårsake utslipp? (Fra containeren ankommer havnen, til containeren forlater havnen).

Flytting av containerterminalen

Hensikten med denne seksjonen er å få et bedre bilde av flytteprosessen av containerterminalen til Kongsgård/Vige-området.

- Hvilke fordeler ser du ved å flytte containerterminalen til Kongsgård/Vige-området?
- Er det noen ulemper ved å flytte?
- Hva er budsjettet for dette prosjektet?
- Hvis Kristiansand Havn får grønt lys til å begynne flytteprosessen av containerterminalen, hvor langt tid vil dette ta?
- Har Kristiansand Havn utarbeidet planer angående utbygging av infrastrukturen rundt Kongsgård/Vige-området (El-kraftnett, vei etc.)?

Avslutningsspørsmål

- Hvordan vil du beskrive omstillingsevnen i forhold til ny teknologi og/eller endringer i prosesser hos de ansatte i Kristiansand Havn?
- Hvordan vil du beskrive omstillingsevnen i forhold til ny teknologi og/eller endringer i prosesser hos havnebrukere (transportører og rederier)?
- Er det noe vi ikke har snakket om, men burde ha snakket om?

Appendix E

Interview Guide - Former RedRock.AI

Generelt

- Er du kjent med begrepene *Smarthavn/Smart Port/Port 4.0*?

Kompleksitet

Havneorganisasjoner

*Hensikten med denne seksjonen er å kartlegge omfanget av organisasjoner og interessenter som er relatert til containerterminalen og dens logistikkjede.

- Kan du gi oss en oversikt over havneoperatører, bedrifter og organisasjoner som arbeider i forbindelse med containerterminalen?
- Er det noen andre involverte parter?
- Kan du beskrive havneanløpsprosessen?

Havnebrukere

- Hvilke rederier bruker havnen?
- Hvem er transportørene/spedisjonsbedriftene?

Havne- og terminalmarkedet

Hensikten med denne seksjonen er å kartlegge konkurransen mellom Kristiansand Havn og andre havner.

- Er Kristiansand Havn konkurransedyktig i forhold til andre havner? Hvorfor/hvorfor ikke?
- Er det noen tjenester som Kristiansand Havn tilbyr som ikke tilbys i andre havner? Hvilke?
- Har du oversikt over digitaliserings- og innovasjonsprosesser i konkurrende havner?
- Opplever Kristiansand Havn konkurranse fra landtransportselskaper? På hvilken måte?
- Hvordan påvirkes Kristiansand Havn av nye/endrende kommunale -og statlige regler og forskrifter? I så fall, begrenser dette effektiviteten i havnen?
- Anses utbygging av nye havner som en trussel for Kristiansand Havn?

Automasjon

Hensikten med denne seksjonen er å kartlegge automasjon i forbindelse med containerterminalen.

- Hvilke automatiserte prosesser anvender Kristiansand Havn i dag?
- Kan de nye kranene i containerterminalen styres trådløst/eksternt?
- Er det mulig å helautomatisere de nye kranene?

Kommunikasjon og informasjonsflyt

Hensikten med denne seksjonen er å kartlegge informasjonsflyt og kommunikasjon mellom havnebrukere, havneorganisasjoner og havneoperatører i forbindelse med containerterminalen.

- Hvordan vil du vurdere kommunikasjonen og informasjonsflyten mellom havnebrukere, havneorganisasjoner og havneoperatører?
- Hvordan vil du beskrive kommunikasjonen og informasjonsflyten med havneoperatører?
- Anvender aktører i Kristiansand Havn (havneoperatører, havnebrukere etc.) ulike informasjonssystemer?
- Muliggjørende teknologier (teknologier som legger til rette for moderne løsninger og systemer)
  - Hvordan er rekkevidden, hastigheten, stabiliteten og tilgjengeligheten på WiFi-nettverket?
  - Hvilke systemer anvender Kristiansand Havn for å spore skip?
  - Benytter Kristiansand Havn elektronisk datautveksling (EDI - Electronic Data Interchange)? Unngås bruken av håndskrevne dokumenter? I hvilken grad?
- Har Kristiansand Havn tilgang til havneoperatørenes digitale informasjonssystemer eller informasjon som inngår i disse systemene?
- Har Kristiansand Havn et datasenter per dags dato? Hva brukes det til? Hvem har tilgang?
- Hvilke tiltak gjøres det for å opprettholde cybersikkerheten?

Bærekraftig energiforbruk

Hensikten med denne seksjonen er å danne et overordnet bilde av energiforbruk knyttet til containerterminalen.

- Hvor lang er vanligvis ventetiden til skip under havneanløpsprosessen?
- Er det andre flaskehalser som kan forårsake for eksempel utslipp? (Fra skipet ankommer havnen, til containeren forlater havnen).

Flytting av containerterminalen

Hensikten med denne seksjonen er å få et bedre bilde av flytteprosessen av containerterminalen til Kongsgård/Vige-området.

- Hvilke fordeler ser du ved å flytte containerterminalen til Kongsgård/Vige-området?
- Er det noen ulemper ved å flytte?
- Hva er budsjettet?
- Hvis dere får grønt lys til å begynne flytteprosessen av containerterminalen, hvor langt tid vil dette ta?

Avslutningsspørsmål

- Hvordan vil du beskrive omstillingsevnen til de ansatte i Kristiansand Havn?
- Er det noe vi ikke har snakket om, men burde ha snakket om?
- Andre ting som vi burde ha tatt opp til diskusjon?

Appendix F

Interview Guide - Seafront

Generelt

- Er du kjent med begrepene *Smarthavn/Smart Port/Port 4.0*?
- Hvordan opplever du havnebrukernes villighet til å tilpasse seg endrede prosesser i havnen?

Havne -og terminalmarkedet

Hensikten med denne seksjonen er å kartlegge konkurransen mellom Kristiansand Havn og andre havner.

- Er Kristiansand Havn konkurransedyktig i forhold til andre havner? Hvorfor/hvorfor ikke?
- Er det noen tjenester som Kristiansand Havn tilbyr som ikke tilbys i andre havner? Hvilke?
- Har du oversikt over digitaliserings- og innovasjonsprosesser i konkurrende havner?
- Opplever Kristiansand Havn konkurranse fra landtransportselskaper? På hvilken måte?
- Hvordan påvirkes Kristiansand Havn av nye/endrende kommunale- og statlige regler og forskrifter? Begrenser dette effektiviteten i havnen?
- Anses utbygging av nye havner som en trussel for Kristiansand Havn?

Kommunikasjon og informasjonsflyt

Hensikten med denne seksjonen er å kartlegge kommunikasjon og informasjonsflyt kommunikasjon mellom havnebrukere, havneorganisasjoner og havneoperatører i forbindelse med containerterminalen.

- Hvordan vil du vurdere kommunikasjonen og informasjonsflyten mellom havnebrukere, havneorganisasjoner og havneoperatører?
- Hvordan vil du vurdere kommunikasjonen og informasjonsflyten i Kristiansand Havn?

Flytting av containerterminalen

Hensikten med denne seksjonen er å få et bedre bilde av flytteprosessen av containerterminalen til Kongsgård/Vige-området.

- Hvilke fordeler ser du ved å flytte containerterminalen til Kongsgård/Vige-området?
- Er det noen ulemper ved å flytte?
- Hva er budsjettet for dette prosjektet?
- Hvis dere får grønt lys til å begynne flytteprosessen av containerterminalen, hvor langt tid vil dette ta?
- Har Kristiansand Havn utarbeidet planer angående utbygging av infrastrukturen rundt Kongsgård/Vige-området?
  - Vil det være behov for utarbeiding av ny vei?
  - Vil det være behov for utarbeiding av jernbane?
  - Vil det være behov for å bygge ut annen infrastruktur?

Avslutningsspørsmål

- Hvordan vil du beskrive omstillingsevnen til de ansatte i Kristiansand Havn?
- Er det noe vi ikke har snakket om, men burde ha snakket om?