UNIVERSITY OF GOTHENBURG

SCHOOL OF BUSINESS, ECONOMICS AND LAW

Smart Port Framework

A study of Port of Gothenburg

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Abstract

The increase in global trade have resulted in the need for more complex infrastructure to support the increased amount of freight. This combined with the advancement of digitalization in society has resulted in the need logistics hubs to adapt. This development has resulted in the 5th generation of parts, the smart port. A port integrated with advanced ICT systems and automated equipment.

In this thesis we want to create a framework, fit for today's challenges in order to evaluate how far a port has come in its transformation into a smart port. This will be done by building our own framework based on other researchers previous attempts to develop such a framework. We have decided to focus on the 4 following pillars, Operation, Environment & Energy, Digitalization and Cyber-security as we found that these measurements are most fit for a smart port evaluation. This thesis will evaluate the ports of Rotterdam, Hamburg and Antwerp. After getting a understanding of how far the market leaders have gotten in the smart port transformation, we will compare the results to the Port of Gothenburg in order to find strengths, weaknesses and hopefully how the Port of Gothenburg should continue in their transformation process.

Our findings are that creating a reliable and in-depth Smart Port Framework was difficult under our short time frame. We do believe however that our chosen domains, Operations, energy & environment and digitalization are relevant when evaluating Ports. This together with our inclusion of Cybersecurity creates a starting point for future research.

Port of Gothenburg (PoG) has a great potential for improvement in the Operations and Sustainability domains. Our evaluation shows that the technological leaders scored more than double compared to PoG when it comes to the operations domain. The specific weak points identified are automation and efficient use of the current infrastructure. Due to the subjective nature of the Digitalization and Cyber Security domains it’s hard to make a conclusive comparison with the other ports. We can however say that these areas shouldn’t be the focus area of improvement for PoG as our findings puts them on pace with the market leaders.

Keywords: Smart port, automation, digitalization, maritime transport

1 Introduction

1.1 Importance of ports

Ports have always been important historically as a focal point for trade due to the easy access the oceans offer to the rest of the world and cost efficiency of shipping, (Alexandersson, Norström, 1963). The increased pressure to become more sustainable and reduce the greenhouse gas emissions by the transport sector will only increase the reliance on ports. This can be seen in the EU which wants to promote intermodal transportation using short sea shipping and railways to reduce the environmental impact this sector has (López-Navarro 2014).

During the World Maritime day 2016 UN Secretary-General Ban Ki-moon said "Maritime transport is the backbone of global trade and the global economy". The global economy would grind to a halt without the shipping industry providing cost-efficient transportation around the world, moving raw materials to factories and finished goods to consumers (United Nations 2020)

Having a well-functioning port can be a big competitive advantage in the global market. The companies in the region of the port get access to one of the cheapest transportation modes there is and easy access to the whole world (Tally, 2012). As an example, the shipping industry accounts for 74% of the volume of goods imported and exported for the European Union (European Union 2015). This highlights the importance of well-functioning ports for nations and regions (International Chamber of Shipping 2020)

Maritime transportation is the most effective mode to transport large quantities over long distances due to big competitive advantages (Rodrigue, Comtois, Slack 2013). When the initial investment of a port has been made it is connected to every other port around the world which can be reached. Comparing this to rail and road transportation where there has to be infrastructure connecting locations to enable goods to be transported between them (Rodrigue, Comtois, Slack 2013).

The increased globalization of the world has increased the demand for shipping. To satisfy this demand the shipping industry has developed longer and wider ships to fit more cargo. This has also made possible for the phenomenon of economies of scale, ie when the magnitude of production increases, you lower your costs. This is because there are more goods that share the production cost. For the shipping industry, this is most evident when it comes to the production of larger ships (Investopedia 2020).
This size increase has led to an increased centralization of the global trade due to fewer ports being able to service the larger ships (Tally, 2012)

Table 1. Port development throughout the history

Generation	**period**	**Characteristics**
1st "Isolated ports"	pre 1960s	Beginnings of mechanical operations in the port and was the foundation for intermodal transports
2nd "expanded ports"	1960s	The ports expanded and became more intertwined with industrial and commercial activities.
3rd "Container ports"	1980s	Global containerization and intermodal transport took stride. This made international production and distribution possible and the ports became a key component of the global supply chain.
4th "Integrated ports"	1990s	The ports grew and continued to facilitate international trade and improved on the 3rd generations information and communication technology.
5th "Smart ports"	2010s	A port characterized by a skilled workforce, knowledge sharing, optimized operation and a sustainable mindset.

Source: Own illustration from article by: Molavi, A; Lim, G and Bruce Race, 2019.

1.2 Smart ports

The increase in global trade has put pressure on the maritime transport industry to adapt in order to provide an efficient service. The amount of actors involved in the supply chain has created a complex web of information that has to be easily digested in order for its participants to make the right decisions (Douaioui et al. 2018). In order to provide this service, the ports need to improve the interconnection and simplify communication between the different actors within the sector. This interconnection enhances and builds upon coordination between operators, improves communication and innovative business models. Ultimately paving the way for improvement with the port and maritime industry (Douaioui et al. 2018).

In order for these interconnections to function properly, the ports need to improve within 3 areas. Primarily the port needs to develop a smart information system. This system assures a

smooth transition of data and information between the different actors within the port. This reduces the amount of lead time and unnecessary labour, making the port more efficient in its operations. As a continuation of the first area, the second part is an improved data centre. As the port expands, so does the need for efficient data storing and assessing. In order to benefit from being a smart port, a system to analyse the information is needed. Third and last, the Port needs to improve their cyber security. When a port becomes more digitized, so does their vulnerability to cyber-attacks and a well-developed security system and make sure that the integrity of the data is not violated (Douaioui et al. 2018).

The increase in containerization and standardization regarding freight has also been a key component of the development of smart parts (Douaioui et al. 2018). The importance of containerizations is based on it being an intermediate tool, meaning it can be transported by sea, railway and roads. The standard measurements of the container allow this way of transportations and is a fundamental piece in order to build a smart port (Hlali, Hamami 2019)

Another characteristic of a smart port is the adoption of sustainable solutions to combat the global environmental challenges. A smart port is expected to reduce the environmental footprint by altering its energy sources to renewable ones and increasing the port's efficiency. A smarter port system has the potential to reduce lead time - the time it takes to initiate a project until its complete. Lead time creating activities can for example be delayed deliveries or administrative work, points that smart data systems can decrease (Douaioui et al. 2018).

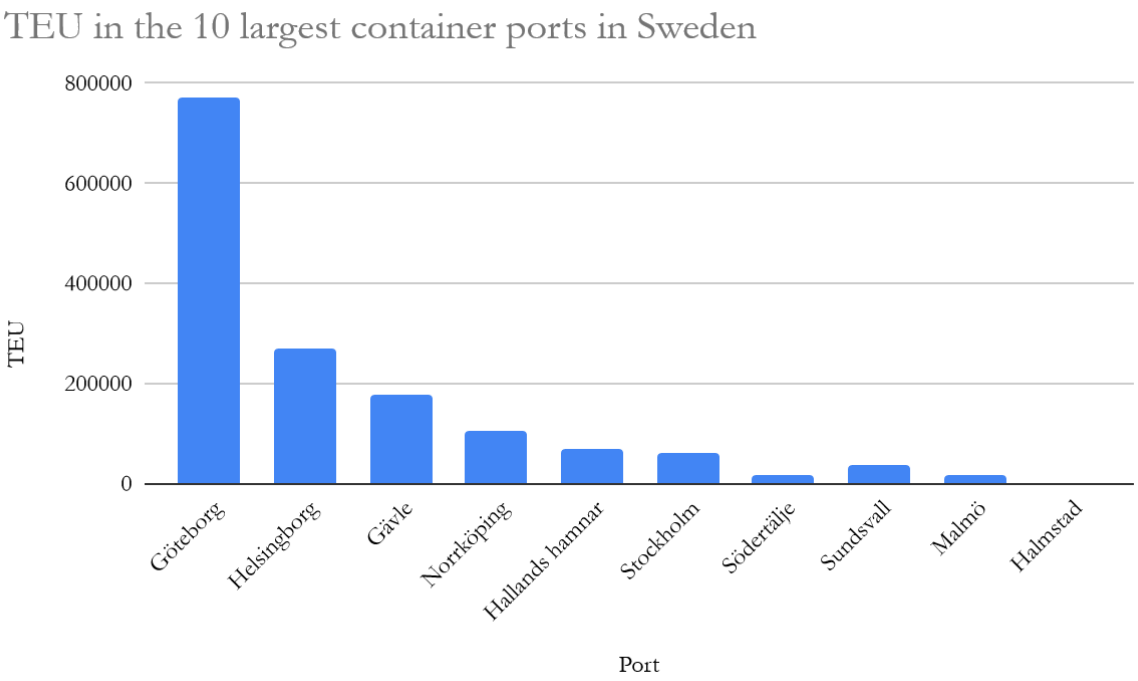
The current market leaders regarding the implementation of smart ports can be found in Europe, outscoring both North America and Asia being the 3 largest trade economies in the world, since the top 10 countries regarding trade of goods and services can be found within these 3 regions (Koopman and Maurer 2019). Heavily trafficked European ports such as Rotterdam, Hamburg and Antwerp can be regarded as market leaders as they scored the highest when the ports were evaluated in 2019 (Molavi, Lim, Race 2019). This can be credited to Europe being a major economical hub and its willingness to innovate. This was backed by a regression analysis performed by Molavi, Lim & Race which found that the previously mentioned European ports scored high when comparing the Smart port score to the regions Gross Domestic Product (GDP) and research and development (R&D) expenditures. For example, the port of Busan scored as the 4th smartest port in the article, but had significantly lower smart port score, GDP and R&D expenditures than the European ports, namely Rotterdam, Hamburg and Antwerp, further indicating a correlation between the variables (Molavi, Lim, Race 2019). This raises

the question of smart ports functionality within smaller economic areas and where less trade is being conducted.

1.3 Port of Gothenburg

Port of Gothenburg is a central hub for container freight forwarding in Sweden as it is responsible for approximately 60% of Swedish container trade (Port of Gothenburg 2020). On top of that it is also responsible for 30% of Swedish foreign trade (Gonzales-Aregall, 2018). Comparing the volume that is being handled in Swedish ports it is clear that Gothenburg plays a significant role in Swedish supply chain. Port of Trelleborg, which is the second largest behind Gothenburg Handles a volume of approximately 10 mil tons of goods, while Port of Gothenburg takes in about 40 mil tons. (Gonzales-Aregall, 2018) This can be visualised below where the number of 20-foot containers (TEU, twenty-foot equivalent unit) the different ports handled in 2019.

Table 2. Overview of 10 largest container ports in Sweden



Source: Own elaboration based on data from the Port of Gothenburg

Being a key agent within the Northern European trade network, the implementation of a smart port concept could have a lot of upside. Such a change could reduce lead time, better

administration and reduce the environmental impact of the port. In addition to benefit the Swedish supply chain, a betterment in the Port of Gothenburg could have an impact on the larger supply chain in Scandinavia. Being located in the centre of the Scandinavian capitals and having great pre-existing rail and road links to both Norway and Denmark makes port of Gothenburg an interesting subject to study with a lot of potential (Port of Gothenburg 2020).

Another point of interest with the port of Gothenburg is the late situation regarding the conflict between the terminal operator - APM, and the workers union. Since 2016 The port of Gothenburg has been dealing with strikes by the trade union "Hamnfyran" after APM refused the port workers collective bargaining agreement. This has had a massive effect on the port's productivity as it roughly dropped by 20% in correlation with the strikes. Additionally, since the port is a key component of the major Swedish supply chain, these disruptions in the port have come to damage the companies that depend on the port for their operations. (Gonzales-Aregall, 2018) Automating and digitalizing the port could be a possible solution for the problem. In this report we will not be diving further into the socioeconomic effects of making the port of Gothenburg smarter, however, we think it is a subject that needs further research in order to make an informed decision about the smart adaptations in the Port.

1.4 Cyber security challenges

The ports are facing pressure to digitalise and adopt new technologies in order to remain and increase their competitiveness on the global market. The risk management in the industry has traditionally been focused on the physical safety of the port and its operations. The first time cyber security was addressed at the international level was 2017 through recommendations and guidelines (Drougkas et al. 2019).

The vulnerability of new digitised systems became apparent in the Maersk cyberattack of 2017. A virus spread within the computer systems which led to a halt in operations in a majority of their businesses. The monetary loss was estimated to be 200 - 300 million USD. This is not to mention the harm to the reputation and the time it took to unwind the damage caused by the virus (Gronholt-Pedersen 2017).

1.5 Purpose

The purpose of this paper is to find out how to evaluate a port from a Smart port perspective by doing a literature review finding commonalities in previous research. We will then use this knowledge to compare the Port of Gothenburg to the technological leaders within Smart ports.

2 Research question and Limitations

2.1 Research question

- How to evaluate a port from a smart port perspective?

- How does Port of Gothenburg compare to the technological leaders within Smart Ports in Northern Europe?

2.2 Limitations

When evaluating the ports, we will only consider the container terminals within the port, we have this limitation to make it easier to compare since the standard measurement of twenty-foot equivalent unit (TEU) is used to measure the throughput of containers. Further we will limit our research to the domains of Operations, Environment & Energy, Digitalisation and Cyber security. This leaves other parameters out of our evaluation and should be taken into consideration when looking at our results. This framework makes a broad evaluation of the port and should not be considered as an in-depth analysis of the smartness, but rather an overview of how a smart port concept is integrated in a port´s daily operations. We will not investigate positive nor negative externalities of a smart port transformation on its surroundings. However, we believe it is something that should be further explored before making any decisions regarding implementation of smart concepts in a port.

3 Literature review

3.1 Model for evaluating a smart port

When looking at pre-existing frameworks for evaluating a smart port, we wanted to find ones that brought up a broad view of the port's activities.

Table 3. Overview of smart port frameworks

Article	Framework Domains
A Framework for Building a Smart Port and	Operations

Smart Port Index	Environment Energy Safety & Security
Preparation of a Smart Port Indicator and Calculation of a Ranking for the Spanish Port System	Operational Economic Social Political & Institutional Environmental
Digital readiness index assessment towards smart port development	Management Human capital Functionality (IT) Technology Information

Source: Own elaboration

The article (González et al. 2020) brought up an interesting set of pillars, environmental, operational economic, social and political institutional. Another framework that came into consideration was the one presented in (Molavi, Lim and Race, 2019). This framework on operations and climate as important pillars, but also explored energy and safety & security as something to take into consideration. A third framework (Philipp, 2020) had a more managerial approach when evaluating. This framework was based on the pillars Management, Human capital, functionality, technology and information, differencing itself from the other 2 frameworks by focusing its valuation on the port's decision-making and planning. This framework places greater emphasis on innovation work and investments, than the actual physical implementation of smart solutions. However, implementation parameters such as Artificial Intelligence (AI) implementation are also included. Even though the different frameworks have named their pillars differently, we found that they all bring up more or less the same parameters.

During our literature review we found out that there are four common areas that they measure the ports from. These are Operations, Environment, Energy and Digitalization. However, the recent cyber-attacks on the maritime industry have shown there is a fifth area which is also important to evaluate when looking at smart ports, this is Cyber security. As the ports operations and systems become more digital you increase your vulnerability towards cyber threats.

3.1.1 Operations

The primary focus of a container port is to minimize the time a ship stays berthed in their port. This is due to it being one of the primary factors the shippers look at when choosing where to berth (Voss and Stahlbock 2004) To support this focus ports are looking at digitalizing and automating the operations to enable even more efficient handling of the cargo. The improvements made within the operations sphere are divided into two subdomains, productivity and automation. (Molavi, Lim, Race 2019)

The automation sphere supports it by reducing the need for human intervention in the operations of the port. This can range from automated equipment such as cranes to processes (Molavi, Lim, race, 2019) Optimization refers to making the current processes more efficient and streamlined. The effects of automation and digitalization won't have the same influence on productivity if the processes for operating the port are insufficient (González et al. 2020).

Having attractive intermodal solutions such as rail is important for the development of a port. (González et al. 2020). The EU is promoting more sustainable intermodal solutions to reduce the environmental impact of the ports. One of the modes of transportation that the EU is promoting is rail. It has the advantage of being more environmentally friendly than road transportation and also has the added benefit of reducing road congestion (European Commission – Directorate General for Mobility and Transport 2013)

To effectively improve and optimize the way the port operates its imperative that the employees are getting sufficient training to maintain and accrue new knowledge (Molavi, Lim, Race, 2019) The importance of this will only increase as a port automates and digitalizes their operations, the old processes will be redundant and new skills will be required of the workers. As a port digitalises and the supply chains become more integrated they can get better insight to the flow of goods in the terminal. These insights can then be used to further optimize their operations and make them more adaptable to change (Jovic et al. 2019).

3.1.2 Environment & Energy

Since a port can be a source of pollution and other environmental disturbances, it is important to monitor these factors and reduce them as much as possible (Gonzáles et al 2020) Improving a ports Information and communication technology (ICT) and smartness can facilitate this

monitoring and make it easier to identify areas of improvement in the port. This can be achieved by implementing environmental management systems (EMS). The EMS summarizes and reports on the port's activities and makes possible spot areas of improvement (Molavi, Lim, Race, 2019) The most widely accepted EMSs are ISO140001, developed by the international organization for standardization and EMAS, which was developed by the European commission. ISO140001 and EMAS can be classified as more general environmental management systems, but there are also more port specific systems such as PERS that is a continuation of the ISO140001, meaning PERS fulfils the same requirements as ISO140001 but implements certain criteria regarding the ports activities (ESPO, 2020) EMS is important as it is found to have correlation with the reduction of pollution and environmental harm and economic growth. (Naoui, 2015)

Environmental work and improvements is important for the port's survival as it has become more and more regulated over the years (Di Vaio, Varriale, Trujillo, 2019) International institutions such as International Maritime Organization (IMO) and the marine Environment protection committee (MEPC) continuously host conventions putting increased pressure on regulators such as the EU to intervene. Late EU policies aim to guarantee environmental sustainability in the Maritime industry and a key component is to encourage sustainable ports (Di Vaio, Varriale, Trujillo, 2019). Areas of improvement would be waste management, air pollution and ballast water as all three have close ties to the port's operation (Gonzáles et al, 2020).

Another area of consideration when discussing a port's eco-friendliness is the air pollution tied to the port. Primarily these are the emission of carbon dioxide (Co2), sulphur dioxide (So2) and other Particulate matter (PM) that can damage both the environment but can also harm the health of humans and other living species around the port, for example was PM tied to 60 000 cardiopulmonary and lung cancer deaths in 2017 (Framework). Various studies contradict each other when it comes to determining where these emissions originate from, but the areas that occur throughout are the boat engines, traffic and refineries within the port (Mueller et al, 2011) The most obvious solution would be to reduce the emissions but with the increase in trade, does it look like finding a way to store and handle the emissions like a more proper solution. One example of this is a project to store Co2 in the North Sea, a project subsidized by the European parliament earlier in 2020 (Northseaport, 2020).

In line with the increase in sufficient waste and pollution handling, so does the need for efficient energy consumption. As the port becomes larger, more complex and increases its industrial activities, so does its energy consumption. This leaves the port with options to either find a way to decrease its energy consumption or find a way to use renewable energy sources to be sustainable. In order to be effective a smart port should try to combine these options as much as possible (Molavi, Lim, Race, 2019).

A port consumes energy both directly and indirect. (Molavi, Lim, Race, 2019) Direct energy consumption can be derived from the port buildings and offices, in other words the energy consumption that is stable and is not correlated with season or volume. Indirect energy consumption comes from activity depending on how much trade that is being conducted in the terminal, such as cranes or other quay equipment. In order to optimize the energy consumption a port should have a systematic approach to the problem. ISO 50001 is an international standard for energy management and works as a framework for the port to follow in its energy consumption decisions. In combination with a systematic approach, the port should monitor its operation and identify high consumption areas in order to optimize its overall consumption (Molavi, Lim, Race 2019).

In regards to a port's geographical position being close to open water and usually great land masses, it leaves the possibility for use of renewable energy sources. This could be the use of tidal and wave energy to power quay equipment or the construction of windparks off-shore, making it possible to rely on wind turbines to produce energy for the port facilities (Esteve-Pérez, Gutiérrez-Romero, 2015) Other possibilities can be installing solar panels on top of buildings in the port that are exposed to the sun or reusing waste in the port for biodiesel to power vehicles used in the port's daily operations. (Esteve-Pérez, Gutiérrez-Romero, 2015).

3.1.3 Digitalization

Digital innovation is the is a vital part of a port's strive for competitiveness; the most important goal of digital innovation is optimizing the usage of the current infrastructure. The customers of the port which can be shippers, freight forwarders and transportation companies can make better decisions by getting access to better information faster. This can for example be achieved by integration between their business systems or the port enabling track & trace so the status

of a container can be checked digitally. Digitalization is vital for ports to enable them to take part in the global supply chain (Carlan et al 2017).

The increased adaptability and flexibility that digitalization offers is something that the port customers are requesting more and more to better optimize their costs, time and resource usage. Digitalising tasks such as access management for truck visits enables a higher efficiency for the customers due to removing the need to announce your visit at port entry. Digitalization also provides the opportunity to have a track & trace function so the transporters can track the status of their gods in the port and by using this new information make wiser planning decisions (Douaioui et al 2018). These new services are something that customers request more and more to better plan their own operations with the port and is something that ports have to adapt to (Heilig, Lalla-Ruiz, Voß, 2017).

A paperless and single customs window process enables higher efficiency and less risk for human error when declaring goods. This reduction of risk enables containers to leave the port to their final destination faster and frees up space for the port (Di Vaio, Varriale, 2020) It also eases the oversight that is required by government agencies involved in the customs process. (Gonzáles et al 2020).

An important part of digitization efforts are the new skills required by the workers of the port. Manual tasks will get replaced by computers doing the work and to service the new systems new skills are required. It's therefore important to educate the workforce to enable them to continue supporting new initiatives in digitalization. The system users and process owners are often the ones with the best insight into what tasks are the biggest time sinks and should be prioritized to be digitalized or automated (Gonzáles-Cancelas et al, 2020).

3.1.4 Cybersecurity

In order for a smart port to function properly, the port needs to digitize and improve its ICT, moving away from documents stored in cabinets to files stored on large servers. This is good and makes for more efficient and smoother operation, however it comes with the downside of being more exposed to the threat of cyber-attacks. In order to keep and combat these risks a port needs well developed cyber security measurements in place.

The reason for 80-90% of incidents regarding cyber-attacks can be credited to human error (Park et al, 2019). These are often unintentionally and can instead be derived from ignorance and insufficient knowledge regarding cyber security. By clicking links in emails, a co-worker in the park can by accident expose the ports IT-systems to malware which can give hackers and other unauthorized groups access to private data or subject the systems to attacks. These types of attack are often carried out with financial incentive, the data gets encrypted and ports can get it back by paying the hackers for a decryption key, resulting in both a disruption in the port and lowered trust for the port leading to financial loss (Park et al, 2019).

Another reason for cyber-attacks is the use of outdated IT systems. Decision makers tend to have an overconfidence in outdated cyber security such as firewalls and antivirus programs (Park et al, 2019). But as a result of these programs being on the open market, hackers have developed strategies and methods to circumvent these measurements which leads to the need for ports to upgrade to more advanced defence mechanisms (Park et al, 2019) Another approach to the problem is to expand the inhouse department of cybersecurity and prepare by running simulations. With the use of "white hat -hackers" the port can intentionally let them try to hack their IT-systems, with such planned attacks the port can identify areas of weakness and respond by improving the detected vulnerabilities. This ultimately becomes a financial battle because vessels and port systems are expensive to produce and a lot of it was produced before cyber-attacks were a real threat to the maritime industry (Agus Gemilang Gultom, 2018). However, seeing the huge potential losses of a cyberattack, preventing measurements may be preferable. Decision makers need to realize the risk of not having a cyber security mindset when operating the port. When entering into deals and contracts, a port must always consider how this exposes them to attacks and threats (Park et al, 2019).

Sharing best practises and transparency can be another point of interest when preventing cyber-attacks. International commissions such as European Maritime information sharing and analysis centre (ISAC) works with collaboration between the ports when it comes to preventive measures for cyber-attacks. (ENISA, 2017) Information sharing between all stakeholders in the maritime industry is a key component to combat cyber threats and ensure that the ports cyber security is up too standard (Droukas et al. 2019).

4 Methodology

4.1 Research strategy

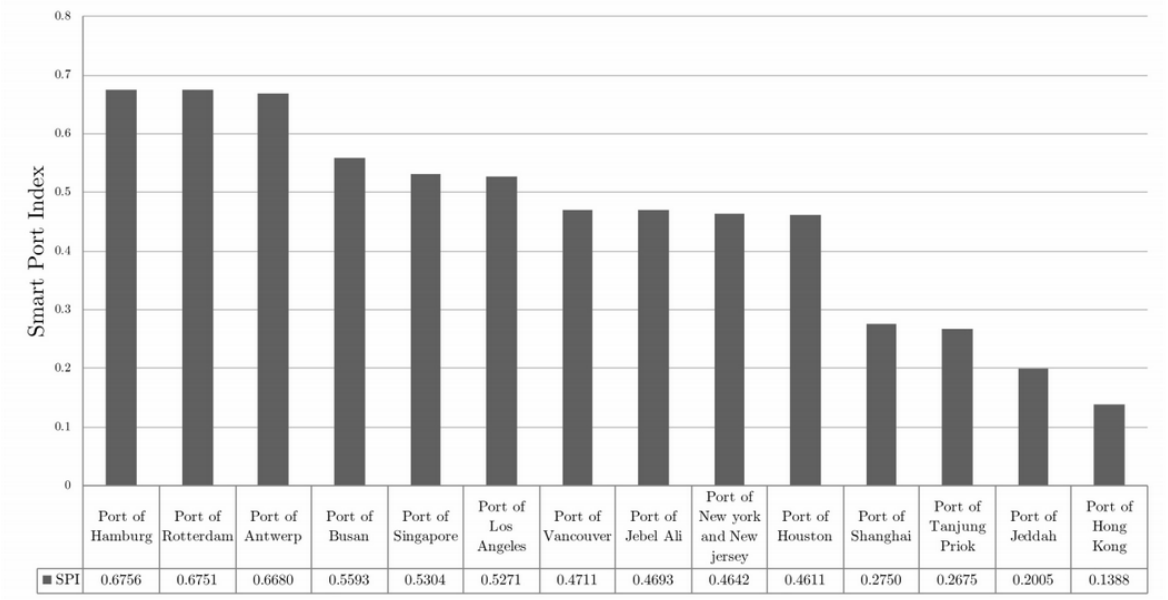
In *Forskningsmetodikens grunder –Att planera, genomföra och rapportera en undersökning* (2011) Patel and Davidsson presents different types of research. The difference between these research strategies based on the researcher's current knowledge in the subject. The research can be of descriptive nature, meaning the researchers are already knowledgeable about the subject, or it can be of exploratory nature, meaning that the researchers collected knowledge during the writing process (Patel and Davidsson, 2011) Since neither of us has a deeper understanding of smart ports before, this paper will be of exploratory nature.

When deciding between a quantitative or qualitative research we initially wanted to conduct a paper based on primarily qualitative research by having a conversation with the different ports regarding their view of our parameters and use quantitative data such as annual reports as a complement. However, our paper will be of both qualitative and quantitative nature since we have relied on both to collect data and statements for our framework. Regarding the qualitative part of our data, we will use secondary data. Patel and Davidsson separates primary data from secondary, primary data being interviews directly tied to the subject at hand and secondary data being data characterized by being created for other purposes than the research itself, but can still be used to draw conclusions about the research subject.

4.2 Data collection

In our data collecting phase we initially tried to reach out to the port authorities for the 4 ports that we wanted to apply our framework to, namely the port of Rotterdam, Hamburg, Antwerp, and Gothenburg.

Table 4. Smart Port Index Overview



	Port of Hamburg	Port of Rotterdam	Port of Antwerp	Port of Busan	Port of Singapore	Port of Los Angeles	Port of Vancouver	Port of Jebel Ali	Port of New york and New jersey	Port of Houston	Port of Shanghai	Port of Tanjung Priok	Port of Jeddah	Port of Hong Kong
SPI	0.6756	0.6751	0.6680	0.5593	0.5304	0.5271	0.4711	0.4693	0.4642	0.4611	0.2750	0.2675	0.2005	0.1388

Source: Molavi, Lim, Race, 2019

Hamburg, Rotterdam and Antwerp were chosen as they were the highest scoring ports in similar evaluation that we found during our literature review, and port of Gothenburg were chosen because we found it interesting to apply the framework to a comparatively small port in order to find areas of superiority and areas of improvement.

When conducting our framework, we will use 4 domains, Operations, Environment & Energy, Digitalization and cyber security. We chose these as we found that variations of the mentioned 4 domains were the most common in previous frameworks and we thought that these domains would give the best and broadest reflection of the port's integration of a smart port concept.
We sent out a questionnaire tied to the parameters we wanted to measure, but as the ports did not answer or were not able to provide the data, we were looking for we decided to collect our data from the ports 5 latest annual reports, sustainability reports and statements made in maritime literature and articles. This gave varying results, the more quantifiable part of the dataset such as annual TEU or emission rates were easy to find in the reports, less quantifiable data such as the integration of cybersecurity were harder to find and would have been easier if the desired discourse with the ports had taken place. This led to us not being able to properly rate the ports in certain parameters and resulted in us having to resort only to reward the ports with a score of either 1 or 0, meaning if it was integrated or not, and not at what degree the certain parameters were integrated.

5 Empirical Analysis

5.1 Market leaders

In order to evaluate the port of Gothenburg we wanted to first look at and evaluate the market leaders regarding implementation of a smart port concept, this in order to create a benchmark and find areas where the port of Gothenburg is lacking or is a potential frontrunner. We have primarily based our decision on the 3 ports that scored the highest in the evaluation (Molavi, Lim, Race, 2019) namely, Port of Rotterdam, Port of Hamburg and Port of Antwerp.

5.2 Parameters to evaluate a port from a smart port perspective

When evaluating a port from a smart port perspective we will be looking at the following parameters.

Table 5. Eriksson & Berlin model

Pillar	**Parameter**	**Definition**
Operations	Docking Line Efficiency	Total TEU handled / Meters of Quay
	Use of storage capacity	Total TEU handled / Container Area
	Degree of automated equipment	Investments and integration of automation in the port
	Intermodality Degree	TEU leaving by rail / Total TEU handled
Environment & Energy	Sustainable work in the port	Work plans for sustainable waste and pollution management
	Renewable energy usage	Investment and usage of renewable energy sources
	Environmental management systems	Certified by internationally recognized standards (ISO140001, EMAS, PERS)
Digitalization	Custom process digitalization	Existence of Single Customs Window solution
	Digitalization of access security	Digitization and automation of access management through technologies such as RFID and OCR scanners
	Integrated digital merchandise management	Existence of digital systems that can help with traceability of merchandise, declarations of weight etc

Cyber security	Cyber security landscape	How well integrated are cyber security in the port's daily operation and future projects
	Upgrade and update	Investment in cyber security
	Information sharing	Active member in information sharing networks

Source: Own Elaboration

5.2.1 Operations

When evaluating a port from an operation perspective we decided to look at how they use their infrastructure, their usage of automated equipment and degree of rail intermodality. Our parameters are based on our findings in our literature review and much of the data needed for them are publicly available with one exception. In our literature review the previous studies usually measures the implementation of automated equipment as a percentage of the equipment in use in the port. Our lack of responses from Port Authorities and terminal operators have left us with the decision to rank this on a scale from 1 to 3. With 1 it not being implemented at all, a 2 meaning it's under implementation and a 3 it’s operational and currently in use.

Operations	**Rotterdam**	**Hamburg**	**Antwerpen**
Docking line efficiency (TEU/Quay)	829	1233	1266
Use of storage capacity (TEU / Container area)	17127	21628	19339
Degree of automated equipment 1 = No automated equipment 2 = Under implementation 3 = Automated equipment in use	**3**	**3**	**3**
Intermodality Degree (% TEU rail / Total TEU)	15%	46,00%	7,80%

Our findings in the literature review points to the operations domain being an important factor when assessing a port. Much of the proposed benefit of digitalization and automation is aimed at increasing the efficiency of the port (Carlan et al.2017).

Our first two parameters are aimed at measuring the efficient usage of infrastructure. The first one, “Docking line efficiency” by dividing the amount of TEU handled by quay meters in the port. And the second, “Use of storage capacity” which derived from dividing the amount of TEU handled by container area.

All of the evaluated ports are working with automation and already have it implemented different ways in their terminals. This ranged from automated guided vehicles for transport and automated cranes. Examples from the ports being:

- Port of Hamburg has automated guided vehicles in use transporting containers within the terminal (Port of Hamburg, 2020)
- Port of Antwerp has opted to implement automated stacking cranes for use in their container storage area (Port of Antwerp, 2020)
- Port of Rotterdam has fully automated cranes for loading and unloading ships and automated guided vehicles to transport containers within the terminal (Port of Rotterdam, 2020)

Since all of the ports have automated equipment in use, they've all scored a 3 on the parameter "Degree of automated equipment".

The importance of evaluating rail intermodality is two folded. It reduces the load on the road network and is more environmentally sound than road transport. It's measured as a percentage of containers entering/leaving the port by rail divided by the total amount of containers entering/leaving.

5.2.2 Environment & Energy

When evaluating a port sustainability from an energy and environment point of view, we decided to look at how the ports manage these topics and if there is an environmental management system in place. Initially we wanted to work with quotas from the ports and find out how they work with sustainability, for example much of their energy usage within the port originates from renewable sources. However, we were not able to find such data and after not hearing back from the ports after several emails, we decided to work with a grading system instead. We decided to research the different ports web pages and read how they work with sustainability and what improvements and plans for the future that are in play. With this system in play, we graded the ports from a scale from 0-3.

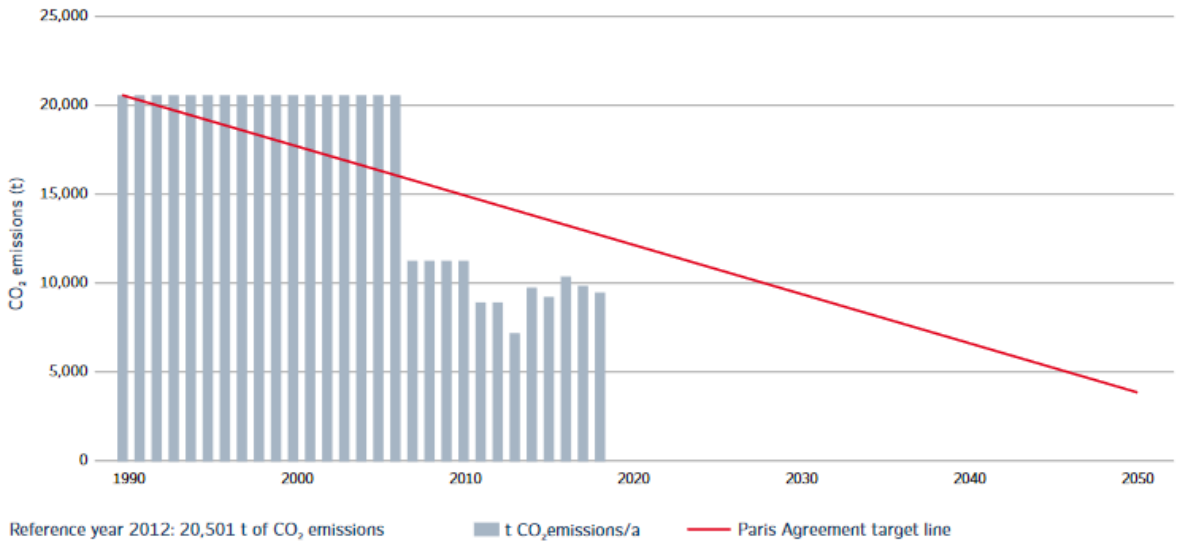
Energy & Environment	Rotterdam	Hamburg	Antwerpen
Sustainable work in the port 0 = No sustainable work 1 = Basic sustainable work 2 = Advanced sustainable work 3 = Very advanced sustainable work and develops new methods for become more sustainable	3	3	3
Renewable energy usage 0 = No renewable energy usage 1 = Basic renewable energy usage 2 = Advanced renewable energy usage 3 = Very advanced renewable energy usage and develops new methods for renewable	3	2	3
Environmental management systems (ISO 140001, PERS, EMAS) 0= Does not work with a EMS 1= Does work with a EMS	1	1	1

When choosing domains to evaluate the ports, we wanted to have broad domains in order to get an overall view regarding how the port works with energy and environmental questions. When looking at sustainable waste management and air pollution we looked for factors such as recycling plants within the port, carbon dioxide conservation and incentives such as subsidies as warrants for vessels to recycle. All 3 ports all have in-depth sustainability reports that describe how they work to develop and make the port more sustainable. All 3 ports have cantered their work around the 17 global sustainability goals and identified that they all have a great responsibility to improve. The Port of Antwerp means that the best thing they can do, regarding waste management, is to provide the opportunity for vessels to recycle and take care of their waste (Port of Antwerpen, 2020). For example, they work with making the sustainable option as easy as possible and have introduced a refund system. The vessels pay a fixed fee for waste collection, but if the vessel dispose of their waste in a correct way at one of the recycling centres in the port of Antwerp, part of the initial fee is refunded. This is to encourage the vessels to make sustainable decisions by giving them a financial incentive (Port of Antwerpen, 2020)

Another point that we took into consideration when evaluating the sustainability of a port is its work to reduce emissions. An example of effective emission reducing work can be found in the Port of Hamburg. By becoming more digital they have managed to reduce their use paper, resulting in less environmental harm. Furthermore, they have invested in their vehicle fleet resulting in 33,2% of the vehicles in the port being electric vehicles. This in combination with

reducing the use of fossil fuels have resulted in 128,386 tonnes of CO2 being avoided in 2018, putting them on pace to manage the Paris agreement target (Port of Hamburg, 2018)

Table 6. CO2 emissions in the port of Hamburg



Source. Graph from Port of Hamburg sustainability report 2018

Deduced from the port's sustainability reports it is shown that all 3 ports have implemented sustainability in their operation and have been able to exceed international standards and are continuing to innovate. This has granted all 3 ports a score of 3.

We had a similar approach when evaluating renewable energy. Since a port is very energy dependent, we thought that the use of renewable energy would have a significant impact on the overall environmental harm that a port can have. We looked at factors such as where the port sources its energy from and how they use their land to develop renewable energy within the ports. An instance of this is the investment in wind turbines at the port of Rotterdam. The port of Rotterdam has at the end of 2020, 102 turbines along its shoreline, resulting in the production of 297.6 megawatts of Energy which roughly equals enough power to power 108 000 households. (Port of Rotterdam, 2020) Similar work can be found in Antwerp, the port has over the last decade installed more renewable energy sources and are becoming more sustainable.

Antwerp has implemented wind energy like Rotterdam, but Antwerp has also made adjustments to rely on hydro turbines, sourcing energy from turbines that spin due to the shifting water levels in the port. (Port of Antwerp, 2020) It is these initiatives combined with

the amount of their total energy consumption that is being sourced from renewable sources that results in both Rotterdam and Antwerp scoring a 3. Hamburg has also installed wind turbines and are making initiatives towards renewable energy (Hamburg Marketing, 2021). However, compared to the other 2 ports, Hamburg has a lower renewable energy quota, this has resulted in Hamburg only scoring a 2 out of 3.

Finally, we looked at if the ports had an Environmental management system (EMS) to structure their work around. We wanted EMS to be widely accepted and hence decided to limit us to ISO140001, EMAS and PERS in order to get credible results from our data. The implementation of EMS has had proven success within other organisations so we considered that this is something that should be rewarded within the framework of smart port valuation.

5.2.3 Digitalization

When evaluating a port in regard to their digitalization we looked at the digital services offered by the evaluated ports. The three parameters are scored with a 0 for it not being implemented and 1 for it being implemented. Since the nature of these services are for customers of the port, we used the websites of the ports to find the required documentation.

Digitalization	**Rotterdam**	**Hamburg**	**Antwerpen**
Customs process digitalization	**1**	**1**	**1**
Digitalizing of access security	**1**	**1**	**1**
Integrated digital merchandise management	**1**	**1**	**1**

All of the evaluated ports have digital platforms for integrating with them(Swzmaritime, 2019). For example, the Port of Rotterdam has an advanced system called Portbase which all dutch ports take part in which offer services within all the parameters we're looking at. This ranges

from submitting customs documents online to pre-notifying your pickup of a container after the system verifies it's available for pickup (Portbase, 2021)

Port of Hamburg has a system called TR02 in place for booking a time slot for either pick-up or delivery of containers to their terminals. This combined with their COAST 3 web portal where customers can track the status of their containers and also retrieve reports enables them to get a 1 for both *Digitalizing of access security* and *Integrated digital merchandise management (*HHLA, 2020). The German customs have implemented a digital system for the customs process called ATLAS. This digital process is also required to be used and you get your notices electronically as well within the system. (Zoll, 2020)

Regarding the Port of Antwerp, they are using a platform called C-point where all interactions with the Port are facilitated. The services offered ranges from tracking containers, declaring goods electronically and arranging pickup in the terminals. These interactions can either be done within their web portal or by integrating your business system with the Port (C-point 2020). From the start of this year, they've also implemented a new system for the release of containers. It's replacing their old pin-code system which was deemed to be too un-secure since the time between creating the code and a container being retrieved could sometimes be considerable. The benefits of the new system is the increased efficiency due to its digital nature where the information regarding release and pickups of containers are transmitted digitally (Port of Antwerpen, 2020)

5.2.4 Cyber Security

When evaluating a port in regards to their cyber security, we faced difficulties as the ports we contacted did not respond, or were not able to give out much information as it was classified. Because in-depth data was difficult to obtain, we chose instead, like the environment and energy evaluation, to search their websites and see how the port works with, and handles cyber security. Unlike the rating scale, here we instead chose to only reward the ports with 0 or 1 depending on if the different domains are mentioned on the website or not, as we considered it too difficult to credibly grade the ports cyber security work.

Cybersecurity	Rotterdam	Hamburg	Antwerpen
Cyber security landscape 0 = Cyber security is not integrated in daily operations 1 = Cyber security is integrated in daily operations	1	1	1
Upgrade and update 0 = none/small investments in developing software and hardware 1 = Significant investments in developing software and hardware	1	1	1
Information sharing 0 = Is not a member of international recognized information sharing network 1= Is a member of international recognized information sharing network	1	1	1

Cyber security was something that was mentioned throughout all the ports we researched. All mentioned ports write about the importance of cyber security and refer to historical attacks that they or their competitors have been subjected to. Something that was constantly mentioned was how an attack does not damage the port, but rather the supply chain as a whole. This is in line with the literature we have found which also underlines the importance of development in the field of cyber security.

The fact that the ports have a focus on cyber security gets echoed by their investments in preventive measures. All the ports have mentioned in a new statement that they have or are planning investments in cyber security. Port of Hamburg states that Covid-19 has accelerated the move towards digitalized ports and with it, the need for cyber security. During the International Association of Ports and Harbors (IAPH) digital meeting in 2020 did leaders from the Port of Hamburg push the issue and urged other participating ports to invest as well (Safety4sea, 2020). Similar statements can be found on the port of both Antwerp and Rotterdam, which resulted in all ports we examined scoring a 1 in our evaluation.

When evaluating the port's participation in information sharing, we tried to contact the different ports. Port of Antwerp could not elaborate in depth about its cyber security but responded by writing in email that they are members of different information sharing groups, for example European Maritime information sharing and analysis centre (ISAC). We did get a response from the other ports so we tried to look at statements by the port mentioning collaboration with different ports. Port of Hamburg, as previously mentioned, is a strong advocate of information sharing in European ports (Saftey4sea, 2020) Similar statements have been made by the port

of Rotterdam and a collaboration between Rotterdam and Hamburg in 2018 was carried out to improve arrival and departure times (JOC, 2018). These statements have resulted in all ports scoring a 1.

6 Results

6.1 Evaluation of Port of Gothenburg

Operations	**Rotterdam**	**Hamburg**	**Antwerpen**	**Göteborg**
Docking line efficiency (TEU/Quay)	829	1233	1266	448
Use of storage capacity (TEU / Container area)	17127	21628	19339	9650
Degree of automated equipment 0 = No automated equipment 1 = Basic automated equipment 2 = Advanced automated equipment 3 = Very advanced automated equipment	**3**	**3**	**3**	**0**
Intermodality Degree (% TEU rail / Total TEU)	15%	46,00%	7,80%	40%
Energy & Environment	**Rotterdam**	**Hamburg**	**Antwerpen**	**Göteborg**
Sustainable work in the port 0 = No sustainable work 1 = Basic sustainable work 2 = Advanced sustainable work 3 = Very advanced and develops new methods	**3**	**3**	**3**	**1**
Renewable energy usage 0 = No renewable energy usage 1 = Basic renewable energy usage 2 = Advanced renewable energy usage 3 = Very advanced renewable energy usage and develops new methods	**3**	**2**	**3**	**1**
Environmental management systems (ISO 140001, PERS, EMAS) 0= Does not work with a EMS 1= Does work with a EMS	**1**	**1**	**1**	**1**
Digitalization	**Rotterdam**	**Hamburg**	**Antwerpen**	**Göteborg**

Customs process digitalization	**1**	**1**	**1**	**1**
Digitalizing of access security	**1**	**1**	**1**	**1**
Integrated digital merchandise management	**1**	**1**	**1**	**1**
Cybersecurity	**Rotterdam**	**Hamburg**	**Antwerpen**	**Göteborg**
Cyber security landscape 0 = Cyber security is not integrated in daily operations 1 = Cyber security is integrated in daily operations	**1**	**1**	**1**	**1**
Upgrade and update 0 = small investments in developing software and hardware 1 = Significant investments in developing software and hardware	**1**	**1**	**1**	**0**
Information sharing 0 = Is not a member of international recognized information sharing network 1= Is a member of international recognized information sharing network	**1**	**1**	**1**	**1**

6.2 Comparison between Port of Gothenburg and market leaders

In the diagram above, we can see how the port of Gothenburg ranks against the technological leaders in northern Europe. This concludes that the port of Gothenburg is underdeveloped in the operations and energy & environment domains, while they have managed to keep up when it comes to digitalisation and cyber security domains.

6.2.1 Operations

The Port of Gothenburg scored low in all parameters included the Operations domain apart from rail-intermodality. APM Terminals are investing in increasing the operational efficiency of the terminal and it has been growing in recent years but compared to the other ports evaluated they have a long way to go. When it comes to automation the port doesn't have anything

operational but they are investigating the possibility of implementing automation in their operations. (APM terminals, 2020)

Regarding rail-intermodality the Port of Gothenburg is almost on par with the market leader Port of Hamburg. They have profiled their rail-port solution as “Green Gothenburg Gateway” and their aim is to continue to grow this segment to reduce the environmental impact of the port (APM terminals, 2020)

6.2.2 Environment & Energy

The reason for the Port of Gothenburg comparatively low scoring in the Environment & Energy domain is the failure to meet its internal goals. The Port of Gothenburg has set goals regarding sustainability such as lower emissions, its direct effect on their local environment and reducing their use of resources, but has not been able to fulfil them (Goteborgs hamn, 2019). This has resulted in their score of 1. However, they have been able to become more effective in their energy usage and are making strides towards sourcing more of its energy from more sustainable sources. Back in 2016 the Port installed their first liquid natural gas (LNG) bunkering and have since expanded with more LNG-bunkering platforms. It is claimed to be able to reduce emissions of nitrogen oxides and could be potential replacement to more greenhouse gas emitting energy sources (Energinyheter, 2019)

However, this has not been visible in their sustainability report as neither nitrogen oxide nor carbon dioxide has been lowered significantly since 2015 according to their sustainability report (Göteborgs hamn, 2019). Even though Port of Gothenburg's has shown initiative towards improving their energy sourcing, it is their inability to improve their current results leading to their 1 point in our evaluation.

6.2.3 Digitalization

The Port of Gothenburg is on par with the other ports evaluated. Having both digital solutions for customers when it comes to interacting with their merchandise and to set appointments for it to be picked up. Port of Gothenburg has also implemented self-service gates equipped with OCR scanners to reduce turnaround time for trucks delivering and receiving containers within the terminals. This has led to the terminal being well below the European average when it comes to turn around time.

The customs process is digitalized in Sweden by the Swedish Customs and the Port of Gothenburg is integrated with this system. Actors can supply their information by either EDI or through the Swedish Customs website (Tullverket, 2020).

6.2.4 Cyber security

When researching the cyber security aspect of Port of Gothenburg, we did not find any direct statements on neither their website nor statements in literature. However, in a brief email conversation with the head of security in the port of Gothenburg, Thomas Fransson confirmed that cyber security is important in the port. He would not elaborate on the question of how cyber security is integrated in their operations, but assured that they are well aware of the threats towards the port and that it is something that is always considered when taking on new projects, statements that grant the port a score 1 in our framework.
When researching investments in upkeep and update of software and hardware in the port we were unable to find news statements regarding the matter and time limit has made it not possible to get any direct statements from the port. We have found articles discussing improvements in physical security and more advanced information systems regarding hazards, but no major investments directly in cyber security. This has resulted in Gothenburg scoring a 0, meaning that there are some investments made but not to the same extent made by our comparison ports. Finally did Fransson confirm that Port of Gothenburg are part of information sharing networks regarding the prevention of cyberattacks, which puts Gothenburg on pace compared to all the other ports researched.

7 Conclusion

7.1 Framework

Creating a reliable and in-depth framework for evaluating ports proved to be more difficult than we initially thought. The literature and previous frameworks on which we based our paper on, were created under a longer period of time and hence were able to get a more extensive data. The combination of a short time frame with difficulties in getting in touch with the ports has resulted in our framework being shallow. The digitalization and cybersecurity domains were hard to evaluate without getting in contact with the different ports, we believe that interviews or written statements by the people responsible for the different domains in the port would have been a good way of approach. This could give a better understanding of how the

ports approach these less quantifiable areas of work and would have translated to us being able to grade the ports in a more comprehensive way. The other, more quantifiable domains, Operations and Sustainability would also benefit from a conversation with the ports. But as our measurements for these domains can be more easily accessed via annual and sustainability reports, we managed to get enough data in order to create a framework that could rank the ports based on their numerical results. It is easier to conclude that Antwerp is more efficient than Gothenburg as this can be deduced from their dock line efficiency. This compared to their attitude towards cybersecurity of instance, as this is deduced from work culture and management, rather than raw numerical data.

However, when it comes to evaluating a smart port and creating a framework for it, we believe that our chosen domains are relevant for this type of evaluation. Operations, energy & environment and digitalization have been explored in previous frameworks and are appropriate for an evaluation, we believe that the addition of a cybersecurity domain is needed. If a new attempt is made at creating an evaluation framework for smart ports, cybersecurity should be a domain that is being measured.

7.2 Smart port concept in Port of Gothenburg

Based on the results and our framework, we can state that the Port of Gothenburg has great potential for improvement in terms of a smart port concept. The areas of weakness are shown most prevalent in domains of operations and sustainability. Port of Gothenburg is not near the average of our researched technological leaders in terms of operations. The average of both docking line efficiency and use storage capacity for Rotterdam, Hamburg and Antwerp are more than double that of Gothenburg. This is an area of improvement for Gothenburg. However, this does not necessarily have to do with smart port implementation. This is also tied to the physical attributes of the ports. Compared to the container terminals in the other ports mentioned, port of Gothenburg is shallower, meaning that they cannot service larger vessels. Although this is subject to change, the project “Skandiaporten” is under way and is a plan to dredge parts of the port to make it possible for larger vessels to enter (Göteborgs hamn, 2020) It is unclear now how this will affect the ports efficiency but since ports with a deeper terminal has a higher efficiency, we would predict an increase in port of Gothenburg as well.
Another area that hinders Gothenburg's ability to improve its operations is their underdeveloped automation. By implementing automated vehicles in the port, Gothenburg will

be smarter and better adapted to handle the increase in goods in the port in connection with the development of Skandiaporten (Voss, Stahlbock, 2004) Having the results of a developed port and increase in automation would help to get a better understanding of how much of a port's operation effectiveness can be credited to its smartness and how much can be credited to its geographical surroundings.

Furthermore, the sustainability portion is an area where the port of Gothenburg is less advanced than the ports of comparison. Port of Gothenburg are working with sustainability according to their website but are failing to meet the standard in our framework. This could be tied to the port's efficiency. Container ships are large emitters of carbon dioxide and other harmful aerosols, meaning the less time that they have to be stationed in the port, the less environmental impact (Merk, 2014). This could potentially be the root of port of Gothenburg's failure to meet its goals regarding emissions. Another area where Gothenburg can improve is its energy consumption and sourcing. Although some improvements have been made such as the use of LNG and installation of solar panels of some buildings, it is not enough compared to the technological leaders. A project of a wind park similar to the one in Rotterdam was being discussed back in 2014 and Christoffer Åslund, coordinator at Göteborg Energi claims that the area is suitable for the installation of wind turbines. However, this project was challenged in the land and environment court and the project was eventually cancelled (Vindkraftnyheter, 2014). Since 2014 the wind turbines have improved and we believe that the construction of a wind park should be brought up again (Phys.org, 2015)
Port of Rotterdam and Antwerp have seen success and the statements by Åslund back in 2014 makes us think that a wind park connected to the port could drastically reduce environmental harm tied to energy consumption.

Regarding the domains Digitalization and Cyber security, it hard to say how much under or over developed port of Gothenburg is compared to the other ports. From our framework is Gothenburg on pace in these regards. The port has similar implementation of digitization in the workplace as the other ports and should hence not be an area of focus. Investments in digitalization can even be somewhat negative. Because a port's operations are integrated with many other players in the supply chain, the system is based on all players being fairly equal when it comes to digitization. If the port is overdeveloped you run the risk of not being able to utilize the investments, if your partner's still uses older systems that are not compatible with your own (Heilig, Lalla-Ruiz, Voß, 2017)

This ties into the cyber security aspect as well. Like digitalisation, cyber security is based on cooperation between the parties, as they are all dependent on each other. On the other hand, Swedish shipping administration have increased the requirements for cyber security in the maritime transport industry (Sjöfartstidningen, 2020), which can be seen as an incentive for Gothenburg to increase their investments in cybersecurity in avoid being the weak link in the supply chain and to keep up with international standards.

To conclude this paper, we believe that in order for the Port of Gothenburg to keep up with the technological leaders they must increase their smartness by making larger investments in automation of equipment. Automation of the terminal will make the port more efficient (Voss, Stahlbock, 2004). which has the potential to both make their operations better and decrease the port's environmental impact. The “Skandiaporten” project also contributes to the need for automation. In order for the larger vessels to turn a profit, the port needs to be fast and efficient in their off and on loading of cargo (Baik, 2017) If the port of Gothenburg falls behind in the automatization process, they run the risk of losing vessels to other ports that can handle the larger vessels.

Port of Gothenburg has for the last 17 years been the heart of Swedish logistics and with projects for expanding and innovating it is not likely that they will fall behind. (Göteborgs stad, 2021)
However, Port of Gothenburg should look into the implementation of automated equipment in order to keep up with other major ports and to be on the frontier of smart port expansion.

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