CHALMERS

Sustainability in port terminals with the application of Artificial Intelligence

Bachelor thesis for International Logistics Program

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CHALMERS UNIVERSITY OF TECHNOLOGY
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PREFACE

As students of the program International Logistics at Chalmers University of Technology, we had the opportunity to dive into a journey of shipping and explore the upcoming technologies and methods. The emerging technologies can impact the industry efficacy and sustainability by creating new solutions. This bachelor thesis represents our educational journey, which we got to research into the insights of the shipping industry and were also able to study relevant companies in the industry.

The program provided us with fundamental education in the logistic branch, while also giving us an ability to explore new technology. The program's content on logistics, shipping and sustainability provided us with a foundation of knowledge that was necessary to explore the industry's challenges. The primary objective of this bachelor thesis was to explore if Artificial intelligence can influence the social and economic sustainability in Swedish port terminals. We had the pleasure to work with five companies, while three of the companies are terminals and the other two companies are AI consultant companies.

We want to thank all companies who participated in this report and the knowledge and experiences they shared with us. We are grateful for the help and support of our supervisor Fredrik Olindersson, who provided us with valuable feedback and guidance during the writing of the report. We are also thankful for the help and support from our outside consultants that provided us with feedback and interviews.

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SAMMANDRAG

Denna studie undersöker potentialen hos artificiell intelligens (AI) för att förbättra social och ekonomisk hållbarhet inom hamnterminaler genom olika användningsområden så som machine vision", "Machine learning", "machine hearing" och sensorer. AI har möjligheten att förbättra säkerheten för terminalarbetare genom olika AI-lösningar. Dessutom kan tillämpningen av AI skapa analytiska prognoser för att förutse effektivt användande av resurser så som yta, maskiner, och personal. Införandet av AI-lösningar i hamnterminaler kan hindras av tillgängliga data samt den ekonomiska aspekten. Investeringar och tillgänglig data/parametrar är en förutsättning för en effektiv AI-implementering. Ytterligare forskning behövs för att tillhandahålla bevis som stöder AI:s inverkan för att främja social och ekonomisk hållbarhet inom hamnterminalverksamhet.

Nyckelord: Artificiell intelligens, Hamnterminal, Terminal, Maskin inlärning, Ekonomisk hållbarhet, Social hållbarhet, Fyllnadsgrad.

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ABSTRACT

This study explores the potential of artificial intelligence (AI) to enhance social and economic sustainability within port terminal, by using technologies such as machine vision, machine learning, machine hearing and sensors. AI holds promise in improving safety for terminal workers through enhanced equipment monitoring and risk mitigation. Furthermore, the application of AI predictions can create a analytical measurement for facility efficient space utilization and accurate forecasting of goods movement, enable economic sustainability through cost reduction and revenue optimization. However, the realization of AI's potential in port terminals is hindered by economic constraints and data availability. Investments and data input/parameters are crucial for enabling effective AI implementation. Further research is needed to provide evidence supporting AI's role in advancing social and economic sustainability within port terminal operations.

Keywords: Artificial intelligence, Port terminal, Terminal, Machine learning, Economic sustainability, Social sustainability, Utilization.

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ACRONYMS AND TERMINOLOGY

AI	Artificial intelligence
ROI	Return of investment
ML	Machine Learning

1. BACKGROUND

The maritime industry is a cornerstone for global trade, effective and cost-effective transport has highly effected economic growth all over the world. Presently, a high amount of all globally goods transported are at sea and our globalized societies would be impossible without maritime transportation. Seaports are derived from global trade and global networks of transportation. Container transportation stands for roughly 15% (United Nations, 2023) of all seaborne goods measured in metric-tons transported, only oil-products and bulk are bigger, underscoring the profound impact of global trade on container ports. The importance of sustainable shipping in future is mentioned by The World Bank (The World Bank, 2023) and they mention three key areas with high importance for a sustainable future. Greening ships and ports, digitalizing operations, and improving efficiency. Greening ships and ports is to minimize greenhouse gases from shipping and move to more sustainable options to decrease the total footprint of the industry. Digitalization is a key area since an increase of digitalization can improve the efficiency of all maritime activities, but it comes with an increased risk of cyberattacks(United Nations, 2022.) Increased efficiency is highly important since low-cost transportation is needed for trade and economic growth. Ports play an important role when it comes to digitization and efficiency since its operations is highly linked to whole industries operations (Rodrigue, 2020).

Regarding digital development in the maritime sector, The World Bank (2021) stated that the power of digital technology can boost performance and create better possibilities to handle future challenges. One branch of digital technology the industry can benefit from is Artificial intelligence and the usage of AI remains unused and has undeveloped potential. Which is common for all digital technologies according to The World Bank (2021), because of barriers such as legal frameworks, human capital limitations and stakeholders.

“Ports are composed of specialized terminals designed to handle a specific cargo type. An increasing number of port terminals, serving either cargoes or passengers, are managed by operators maintaining an international portfolio” according to Dr.Theo Nottleboom, Dr. Jean-Paul Rodrigue and Dr. Athanasios Pallis (Theo Notteboom et al., 2022).

Ports terminals can have several functions, but they are often specialized in specific commodities and cargo types, such as containers, bulk, and oil. Terminals in ports play a big part in shipping and logistics, both when it comes to effective operations and handling of all types of cargo the industry demands. Providing services for the cargo owners is the base of all terminals, but how they do it up the operators. Therefore, are port terminals operators often linked to shipping lines or cargo owners.

1.1 Aim of the study

The primary objective of this study is to explore the different areas where AI can enhance social and economic sustainability in port terminals. This study focusing on the key areas where AI can improve operations in port terminals. Through a literature collection and interviews of both terminals and AI-suppliers, this study identifies key areas where AI improvements can impact the sustainability work for port terminals.

1.2 Research questions

This chapter, the following question is the base for this report:

1. How can artificial intelligence improve port terminals in terms of social sustainability?
2. How can artificial intelligence improve port terminals in terms of economic sustainability?
3. In what areas can the application of artificial intelligence be used in port terminals?

1.3 Delimitations

This work is limited to Swedish port terminals. The limitation to Swedish terminals is done to get a smaller selection and easier get access to relevant interviews/personnel in port terminals. The term sustainability in this report ignores the environmental aspect of sustainability. This is done due to the broad amount of research needed to cover all three aspects of sustainability.

2. THEORY

In this chapter, the theoretical basis of information will be provided for a deeper understanding of the concepts that are brought up in this report. Port terminals and the different areas of Artificial Intelligence is described.

2.1 Artificial intelligence (AI) a general definition

Artificial intelligence (AI) is a broad and encompassing term referring to a system that is designed to collect dataset and simulate human intelligence in machines, such as thinking and learning. But one important thing with AI is that the possibilities to have a problem-solving capability(IBM, 2024a).

AI is a broad field and has several areas where it can operate. One task can be emulation of human intelligence and behaviour to accomplish given goal through dataset acquisition. The datasets, provided by users or specified source is analysed and processed by AI and mimic cognitive functions of human intelligence. The principal of AI is to analyse, and process given dataset to enabling the performance of various tasks (Fjeld et al. 2020). AI have different segments and is a broad term with various branches such as machine vision, machine learning, digitalization etc.

Applying and understanding AI is a developing process and there are both advantages and disadvantages of artificial intelligence. The application of AI is a method to increase efficiency and minimize errors. Although, it is vital to be precise or otherwise it could result in unnecessary risk and lead to disadvantages (Dr. Ravindra D. Sarode, 2020). According to Dr. Ravindra D. Sarode, (2020), the main advantages when applying into systems are finishing task in a higher rate, minimize human error due to precise practises from AI, possibilities of space utilization in particular areas, multiple functions at the same time, easier and more precise long-term planning, etc. The benefits need to be weight against the disadvantages and the potential risks. Some disadvantages with AI are complicated systems, economically more expensive than conventional methods, replaces certain jobs, when programmed incorrectly it can cause inaccurate results, technology dependency increases. The benefits and capabilities with AI have a role in future efficiency methods but needs to be applied carefully due to the potential drawbacks and risk that can outweigh the advantages if it is applied incorrectly (Dr. Ravindra D. Sarode, 2020).

The topic of strong and weak AI is a theoretical concept of AI to explain a mindset of AI development (IBM, 2024b). According to IBM, strong AI is defined by a system that can perform a variety of task and functions. Strong AI is also able to learn from the experiences and teach itself to solve new problems, it learns and adapt to the surroundings to create the ability to become a self-sufficient and solve problems. Some common terms used as strong Ai are machine learning, deep learning, and pattern recognition. The contrast to this is weak AI and IBM describes it as or calls it “narrow AI”. The purpose of narrow AI or weak AI is to perform a specific task that is given, the AI can only perform one type of task at the time such as answering a type of question. It is co-dependent on human interference due to the ability of performing one task at the time, weak AI depends on manual data input and parameters from humans and cannot self-learn from itself. While strong AI are not required constant data input and over time develop a kind of human-like consciousness (IBM, 2024b)

2.1.1 Machine learning

An additional facet within the realm of AI is machine learning. Machine learning is a branch of artificial intelligence and computational algorithms, and its central point is to use acquired dataset and algorithms to replicate the specific way of human learning (IBM, 2024d). Basically, machine learning is a computer program that uses input data from past experiences to improve performance by learning from these experiences and its surrounding environment. Diverse functions characterize the domain of machine learning, one function of which is to achieve a given task by utilization of input dataset and produce a desired outcome. Another function is to use machine learning to improve performance by data mining. Data mining is a machine learning system that utilizes algorithms to cross-examine vast databases and find hidden information within the data (IBM, 2024d).

Neural networks are a machine learning program that consists of several layers, more than 3 layers are often described as deep learning(IBM, 2024c). The neural networks are based on input layer, hidden layer, and output layer. These neural networks rely on data to train to improve their accuracy, one famous neural network is Googles search algorithm. Neural networks with two or three layers are mentioned as basic neural networks(IBM, 2024c).

The different types of data input that AI can adapt and learn from is wide, one type of data possible for AI to learn and analyse is sounds. This can be seen as machine hearing, but it is machine learning with a different data input. Instead of data from statistics, text, and other types of data sources AI can use sound as the main data source. This is commonly used in hearing aids, where AI can help the hearing by sorting and recognized sounds(Carly Sygrove, 2024). But the use of AI and machine learning is not limited to hearing aids, it is only one example of areas where the AI usage has potential.

2.1.2 Machine vision

The term machine vision or computer vision is not a new term, but the integration with machine learning and deep learning represent a more recent development. To simplify AI-systems helps computers to think, but vision helps computers to see, observe and understand. Machine vision's ability to see are most used for visual inspection and detection, tracking, positions and identifying of objects(Intel, 2024). By analyse and training of data, AI can learn to spot very subtle differences that human is not capable of. But the precision of the system is based on the amount of data and training that are given, therefore there are correlations between the data input, training, and the precision the system is capable to working in(Intel, 2024).

The practises machine vision technology is equipment to increase the ability of analyse and see task such as quality control and worker safety (Intel, 2024). Machine vision is often applied to industrial equipment to improve efficiency and safety for both workers and machines. The common systems applied on industrial equipment are machine vision cameras, embedded IoT sensors, and industrial PCs. The systems can be used for both manufacturing and operations areas in companies, the system for manufacturing is analytical algorithms to assess and inspect the quality control of products that lead to better products, reduce labour cost by eliminating unnecessary steps, increase overall system efficiency by finding ineffective areas. On the operations side, the main objective is improving the worker health and safety. Machine vision systems previously mentioned are used for increasing safety by checking if employees are wearing proper safety equipment and interpret human actions to predict and prevent accidents before it happens. Other functions to improve safety are that AI can use data from cameras, PCs, and sensors to analyse and detect faults and signs from

machines to prevent wear and breakdown before it happens. It improves safety and increases efficiency by preventing unexpected downtime and minimizing costs (Intel, 2024).

2.2 Sustainability

There are three different dimensions regarding sustainability, social, environmental, and economic sustainability. In this report, the primary focus is on social and economic sustainability because of the limited time and resources available to explore the environmental aspect. Sustainability is a highly current topic and port terminals are actively pursuing for improvements within the organisation in regarding sustainability. The key question is the ability to keep an operational profitability while incorporating sustainable strategies. Both social and economic sustainability effectively impact each other because an investment in sustainable tools will improve social aspect and contribute growth to the organization that affect the economic aspect.

There are different strategies of improving sustainability in terminals and the aspect of integrate AI within the organisation is a can be a useful strategy (PwC, 2024). AI integrated strategies consist of development in various tools such as yard cranes, handling equipment, information system and terminal design, to improve sustainability. The strategy affects sustainability since the AI tool can increases efficiency by minimizing errors and energy resources in comparison to older equipment.

2.2.1 Economic sustainability

Economical aspect of sustainability is highly important since economic growth and profitability for the actors in the maritime industry is necessary if the industry should survive in the future.

Economical sustainability refers to support long-term progress and growth for the maritime industry, when it comes to terminals this is highly important. This is because of the amount of infrastructure and investment needed to operate a port terminal. The maritime industry is dependent on long-term thinking because of the huge and expensive investment needed, it can be vessels, ports, and terminals. Another aspect of the importance of long-term thinking is the number of actors involved, when it comes to terminals it can be several actors involved such as the port, the port-city, shipping companies, transport buyers to mention a few. Investment therefore needs to be long-term if they should be economically sustainable.
There is various definition of economic sustainability, the label often gets defined depending on the approach of economic sustainability. One aspect of economic sustainability regarding maritime/terminals is to have a long-term growth within the organisation and withhold vital assets, while maintaining the environmental growth. It refers to sustainable business models to maintain financial growth while improving other areas of the organisation (in this case terminals). As previously mentioned, the aspect of economic sustainability can be divided into various sections to maintain growth, such as investments to both increase the effectiveness of the terminal and therefore increase growth/revenue. Also, the factor of satisfying stakeholders while improving the sustainability aspect. The stakeholders play a vital role in economic sustainability by funding investment for continuous growth in all aspects of sustainable growth.

Economic sustainability in terminals can be described by the available capacity and the percent used of the total Capacity in terminal. To operate the terminal close to total capacity is more sustainable because you are using all available resources to create revenue. The revenue in the terminal divided by the net revenue also gives an indication how economic sustainable

the terminal operator is(Leal Junior et al., 2022). This is necessary for all companies, because a high revenue is the same as a good liability.

AI can contribute to sustainable investment when it comes to the economic aspects of sustainability. This can be done by energy reduction and predictions, maintenance optimization and overall optimization of resources in general. Predictions of resources, investment, maintenance, and operations is all highly important for the container terminals work for economical sustainability. AI is a pertinent subject concerning economic sustainability, the reason is the investment of new technological equipment and systems such as automated cranes, quays, and other information systems. The technological systems and equipment are AI driven and an economic investment by improving efficiency, effectiveness, and longevity of the terminal/terminal equipment, therefore promoting sustainable growth.

2.2.2 Social sustainability

There are many dimensions of social sustainability, but the focus will be from a business perspective of social sustainability. According to (unglobalcompact, 2024) the definition of social sustainability is the quality of a company's relationships and engagement with stakeholders, employees, workers in value chain, local communities, society, and customers.

The measurement of social sustainability is usually not a numerical measure/metric, it is based on a business involvement with contribution to equality and fairness to all factors. For example, a company's safety regulations for its employees. From a business perspective regarding social sustainability, the priority is the work environment for the employees and their rights, this includes employee's health, safety, fairness of labour practices, diversity, and work-life balance. As previously mentioned, it is difficult to measure a business social sustainability, but one metric that make it easier to assess social sustainability is the variety of engagement of the stakeholders and social impact. According to (unglobalcompact, 2024), social impact is anything that affects a business stakeholders' relationship with actors.

According to unglobalcompact, 2024 social sustainability has become more relevant for companies due to how it affects the business. Consumers are increasingly engaged with a company's business strategy and poor sustainability can impact the brand in a negative way. For example, if the quality of the working conditions for the employees are bad such as ignoring safety regulations or bad working hours (work-life balance), the brand image will be hurt, and the consumers and media are able to affect the business negatively. In correlation to bad working conditions, product quality is a byproduct of having a lack of safety and bad working environment. In contrast, good social sustainability can affect the brand positively by having good image.

The aspect does also include a company's or impact to a sustainable society, such as a contribution to more work opportunities to the community(adecesg, 2024) . From a port terminals perspective, other factors to consider when evaluating the impact of a company's or terminal social sustainability is the how the infrastructure gets affected. Port terminals are linked with a lot of infrastructure to and from the cities and measuring the effectiveness (if it is good) infrastructure is a method to evaluate a terminals social sustainability (Bergqvist 2016, Woxenius 2016). Infrastructure are how a city is built such as roads, effectiveness to move around and location of institutions, buildings, etc. A good infrastructure from a port terminal, has an effective method to move goods around while not disturbing other people's movement and day to day life in the city. Indicators are effective railway system in and out from the port, time efficient in and out from terminal facilities, communication between

actors, etc. Although, an investment in infrastructure would improve port terminals, there are various factors such as planning process and previous historic evidence (experiences or other empirical studies) affect the procedure. The lack of concrete evidence of an effective planning process and previous evidence affect the choice of investment from actors (Bergqvist 2016, Woxenius 2016).

2.3 Port terminals

Ports and Terminal operators is highly connected since terminals operates within the port area or in some case in the surrounding area of the port. Therefore, terminals operators are dependent on the port as a node for transport, energy and digital (Lind, 2023). Without a port there would be no port terminals and without a terminal the port wouldn't serve a purpose. Port terminals can serve different service to its customers, such as transshipment, consolidation, storage, and Co-ordination to mention a few services provided by port terminals. These different services are often specialized into a goods segment such as container as an example, where the terminals can adapt their services to provide value to the customers.

As an operator there are three major factors where the importance and competition of a terminal can be measured, it is the location, accessibility, and infrastructure (Rodrigue, 2020). The location is a factor when it comes to which economic area are they serving, there can also be some constrains about the location. This constrains can be land use and congestion caused by the terminal, especially in highly populated areas where the terminal can serve a lot of economic activities, but the footprint of the terminal can affect nearby land. Therefore, many terminals are located close to highly populated area, but outside the central areas of a city. The accessibility of the terminal to other terminals local, regional, and globally is of highly importance. It can be the how well it connects other transport systems, does it have good connections with both rail, sea and road or is limited in its connections between modes. A terminal with good sea connection but with bad inland transport system will be limited in their capacity when it comes to importing and exporting goods because of the inland connections. Terminals often requires expensive investment in their infrastructure, since the operation are dependent on a lot of handling gear and storage. Infrastructure investments are of high importance because they are meant serve the terminals for many years, because of that some predictions of the future are needed to predict technological and logistical changes in the market (Rodrigue, 2020).

Automation in port terminals is applicable for all types of terminals, but the needs differ between cargo types, size, location and capacity. Automation can be described in three main dimensions according to Theo Notteboom, Athanasios Pallis and Jean-Paul Rodrigue (Theo Notteboom et al., 2022)and there are the Yard, the interface, and foreland and hinterland automation. Yard automation can consist of several activities such as yard planning, automated guided vehicles (AGVs) and yard management systems. When it comes to the terminal interface the most common is automated ship to shore cranes and automated gate systems. Foreland and hinterland automation relates to process of the terminal even if they are not directly connected. Automation in the rail and truck systems, but also storage and warehousing connected to the port terminal.

2.3.1 Terminal cost

Terminal cost is important for the total cost of transportation. Therefore, the cost of the terminal is an importance aspect when choosing terminal for your transportation. Cost structure for a terminal can be divided into three main costs according to Jean-Paul

Rodrigue(Rodrigue, 2020), transshipment cost, infrastructure cost, and management cost. The infrastructure cost consists of cost for the infrastructure but also the superstructure needed in port terminals. Examples of this is the constructions in the terminals such as piers, cranes, runways, and warehouses etc. The transshipment cost is cost occurring when unloading and loading goods between modes or to different carriers. Management cost is cost occurring for the management of the terminal and this depend on a bit of the complexity of the terminal. More complex activities in the terminal the more need of a high functional management which can increase cost. One example of this is a railway terminal compared to a port terminal, the railway terminal is only handling goods within the country and with a more limited security then a port terminal which handles exporting goods and importing goods with a higher need of management(Rodrigue, 2020).

Reduced terminal cost has an important role of transporting goods and international trade, but not only in the cost aspect. The way terminal operations can increase the effectiveness of the whole transport system plays a significant role for international trade. This effects the whole transport system since less time in terminals increase the asset utilization. Transport terminals also stimulates the local economy since it is a node of transportation, this affects working possibilities, companies, and local economy in general(Rodrigue, 2020).

Port terminals are often in a need of sever investments in infrastructure and superstructure(Theo Notteboom et al., 2022), therefore stakeholders need to investigate the time it takes to get a return of their investment. ROI is a tool to measure the profitability of an investment (Birken, 2022).The ROI are one way of controlling the possible benefits of an investment for stakeholders. Port terminals needs to forecast the benefits of each investment done in their operations, one example of investment that's needed to prove evidence of good ROI is technical investments such as AI-solutions.

2.3.2 Challenges for Port terminals

The port and city often compete of the same land, because of that the availability of land can be a problem for the port. This will affect the port terminals in a sense of the area a port terminal can operate within. Therefore, if exiting terminals want to increase their capacity and volumes, they still need to operate within the same area as before. This gives the terminal operators a challenge to increase the capacity, the operators need to operate the area with a higher utilization and efficiency(Theo Notteboom et al., 2022).

Internal challenges for ports are divided into three main areas according to Unctad (United Nations, 2022), shipping networks, port level, and hinterland. For the port terminal shipping networks approach and choses of routes plays an important role, but still, it is the challenges on the port level where terminals can affect the most. Such as infrastructure management, space, energy provision, labour, and security. The infrastructure management for ports and terminals is of high importance since it is dependent on various factors such as shipping lines routes and needs, but also the demand from the hinterland connectivity. As already mentioned, the available space for growth are ports often limited, because of the conflict of space with surrounding city or cities. The ports energy usage is a challenge since the they are large consumers of energy, and the maritime sector are decarbonisation their energy usage.

3. METHOD

The report has employed a qualitative research method as a methodology to answer the questions in this report. According to Justesen, Lise & Mik-Meyer, Nanna. (2013), a qualitative research method focuses on collecting and analysing non numerical data about a specific topic. The purpose of the method is to gather insight into a problem and generate new ideas. Evaluating AI applications in terminals requires a in depth analysis and the qualitative research method allowed a more detailed analysis of the subject, and the interviews provide a deep understanding of AI technology and its applications in terminals. The method also allowed us to pick specific companies and terminals that would fit our context and relevance to the subject, such as company industry, location, goals etc.

3.1 Literature collection

A literature review was employed in this report to collect data and information. The aim is to collect data of the subject AI in terminals. The following section will describe how the systematic literature collection was done to find the data to this study. Databases used was Scopus, Google scholar, and Science direct, all providing scientific papers and articles. The choice of these three databases was carefully considered. Although, other literature sources were also used such as various books from Chalmers library. The literature review was made in these following steps.

Step 1
Finding relevant keywords to limit the search of scientific articles and other sources. These keywords consisted of but not limited to. “Artificial intelligence”, “*conventional terminal*”, “automated terminal”, “terminal sustainability”, “Economic sustainability” and “social sustainability”. These keywords were employed across a range of academic databases such as Google scholar, Science direct and Scopus. From this search several articles were recognized/shown.

Step 2
After the initial search, exclusion criteria were utilized to refine the selection of articles, excluding those not pertinent. The criteria limited the articles that were within the last ten years (2014-2024) that were written in English or Swedish. Other exclusions were not peer-reviewed articles, no unrelated to the research topic articles, no unpublish articles and no English or Swedish written articles. Various exceptions were made, such as literature or books from databases such as Chalmers library and sources that were used for definition of various concepts.

Step 3
After the search and exclusion criteria, a quality review on the articles were assessed. The review was based on the reliability, credibility and recently of the articles. The credibility, and reliability of the sources were evaluated and judged by criteria such as biases, limitations (accessibility of the sources) and recent acquired information/studies that have been done. All sources were also evaluated by reviewing the authors of the sources and assess if the credibility of the authors, the process included looking at the authors previous written studies, the occupation of the authors (what filed it research), the education of researcher/professor etc.

In addition to the previous steps, a snowball aspect was implemented to the research and collection of sources. The snowball sampling is a method were articles and sources are used

for finding additional references, for example, looking at another studies reference list to find other relevant sources.

3.2 Primary data

In addition to the literature collection, several semi-structured interviews were employed to add value to the report. It was performed by having interviews with small to middle sized terminals in Sweden, but also companies specialized in AI development. The interviews were of key persons in the terminal such as technology developer and terminal manager. The methodology was selected due to its capacity to conduct an in-depth form of analysis/examination on specific companies. As previously mentioned, the semi-structured interviews allowed the opportunity of a more personalized dialogue with specific companies/terminals.

To perform the semi-structured interviews, a various number of emails was sent to relevant companies and terminals. There were limited number of responses, but those who responded were willing to participate in an interview. The interviews consisted of pre-written and special designed questions for each AI consulting company and terminal, the questions shared with the interviewee before the main interview. There were five interviews in the process, the interviews consisted of three Swedish based terminals and two AI consulting companies. After every interview, a transcript was created and the notes from the interview were discussed. Four of the interviews were executed on the online platform “teams” and recorded for further analysis. The last responder had a different method of interview, the interview consisted of a written response in form of email exchange. The questions were sent to the responder and the answers were given through an email.

The answers from the responders were analysed after all interviews and written down. The analysis consisted of breaking down the result each interview and later finding correlations between all interviews. The interviews were divided into two different groups, first group consisted of the result from terminals and the second group was the answers from the AI consulting companies.

Firstly, an analysis of the terminals was made to find common practises between each terminal, but also evaluate the differences. After the analysis was finished for the first group, the second group needed to be analysed. The same approach was applied to the second group, in other words, try to find similarities and differences in the results from the interviews and discuss it. After the analysis and evaluation of both groups, the result from the first and second group was analysed to find correlations between the groups but also analyse if there were any different practices between the groups. An in-depth analysis and discussion were applied to find if both groups had similar thoughts and ambitions with AI practises in terminals, both current and future practises.

After all the results from the groups were evaluated, the next step consisted of an analysis between the result and the literature collected from previously mentioned sources in the theory. Further discussions were applied to find if the result matched up with the literature. The discussion also included a review of the practises and hypotheses from the literature and the actual practises in terminal. When the final analyses were finished, the results were divided into two different segments, first segment consisted of similarities between result from all responders and the second segment consisted of differences literature and the result from the interviews.

3.3 Bias

According to Justesen, Lise & Mik-Meyer, Nanna. (2013), the criterion for reliability comes from the scientific ideal of strict objective, where there are no variables and research methods get affect by subjective observation such as the research role. Therefore, there is a high ambition on reducing biases, the concept refers to the "skewness" of the survey result regarding the involvement of the researchers or participant.

To minimize the biases, both terminals and AI consultant companies were interviewed to get a realistic perspective to AI functions in terminals and the possibilities in the future. The selection of companies and terminals was limited due to narrow knowledge regarding AI usage in terminals and the limited availability of practice. Another measure implemented to minimize the occurrence of biases; a selection criterion was created during the data collection process.

4. RESULTS

In this chapter, the results from the interviews will be presented and answer the following questions in the "research questions" part of the report. The result is based on the answers from the interview. The interviews consisted of three terminals and two AI consulting companies.

Table 1
This table describes the respondents from the interviews.

Respondents	Description
Respondent 1	Swedish port terminal
Respondent 2	Swedish port terminal
Respondent 3	Swedish port terminal
Respondent 4	AI Consulting Company
Respondent 5	AI Consulting Company

4.1 Future solutions regarding social sustainability in port terminals

The importance of social conditions and workers environment has a history of high importance for ports and terminals. Therefore, the social sustainability work is a key area for operators since they are regulated(AFS 2001-1)by Swedish law to continuously work with this issue.

4.1.1 Informatic system in port terminals

Respondent 1 mentioned that there were several digital systems in terminals, there are several systems with different objectives. Systems for different types of goods such as containers, general cargo, and warehouse storage. But also, there is a system for safety and maintenance in the terminal. These systems have the purpose of providing following things collecting information, storing data, working as a support for workers and storage planning. Terminals use various systems for different tasks and objectives, in many cases systems specific for that one terminal. Terminals also work with IT systems from the cargo owners and there is no general IT system for the whole terminal (Respondent).

Another system employed was a digital information system. According to respondent 1 and respondent 2, the system has only been in practice for about one year and the information system's purpose is to increase the flow of information between different parties and transfer information effectively. We also found that terminals used paper and pen in some cases for planning, but also Excel was commonly used in port terminals. All these systems need to be manually operated to some degree. Terminal 3 mentions that some of their flows have been the same for many years. Therefore, they work with many "old truths" or in other words old experiences for their work in the terminal (Respondent 2).

4.1.2 Sensors in terminals

Another component the interview respondent 5 showed was the usage of censor to integrate AI technology with terminal maintenance and effective service. According to respondent 5, the sensors are used for internal logistics in terminals and the sensors are applied in the terminal facility (usually on ceilings and available walls) to detect both vehicles, materials(goods) and humans. The purpose of the system is to gather data from the sensors and analyze or make statistical data from the censors. sensors are not applied on vehicles

because of various factors such as more advanced technology, financial support, and limited amount of practice rounds. Although, it is a possibility of censoring vehicles can improve terminal handling (Respondent 4).

The data from the censors is put into AI system where it is analyzed and the AI system creates predictions for time intervals regarding handling of the goods in terminal, but also create behavior models for humans. Behavior model is a prediction on how a human should behave(act) during a situation, for example if a heavy package arrives, the behavior model can tell the person how it should handle the heavy goods (Respondent 4).

4.1.3 Solutions with machine hearing

Machine hearing is a future solution for machinery maintenance in terminal. The concept is that AI integrated with sound analyse can detect anomalies in the machinery and alert employees it happens. According to respondent 1, respondent 2, respondent 4 and respondent 5, machine hearing is not anything they are working with in the moment (2024). The respondent 4 and respondent 5 find machine hearing a reasonable solution for terminal development in the future, respondent 4 stated that machine hearing does not need as much training data compared to the concept of predicting time frames in terminals. The training data should only be sound recognition from the different machinery and if the machine does not make the regular sound, the AI should alert the employees about the anomaly. Machine hearing can increase the safety for both workers and machinery, the ability to detect defection on machines will help with workers safety on the workplace. Improved safety and less risk of injury for workers can increase the social sustainability. As previously mentioned, machine hearing can also be a solution for better machine quality due to detect anomalies before it gets critical and contact maintenance before any danger occurs. (Respondent 1), (Respondent 2) (Respondent 4), (Respondent 5).

Increased effectivity and less risk of breakdowns can improve both social and economic sustainability since it will improve safety and reliability of the machines connected to AI supported machine hearing. The social part can benefit from more predictable operations and the need for overtime hours for workers can be limited. Safety will also increase since breakdowns will come with a risk of dangers for workers. The economical aspect of machine hearing in port terminals are connected to the time and labour. Without some breakdowns that AI can predict, the terminal can limit costly breakdowns of the operations. Which could lead to decreased overtime hours for workers and port calls for vessels (Respondent 5).

4.1.4 Safety and Quality work in terminals

Terminals work with Safety in many different areas, but it can be divided into workers safety and safety for equipment and goods. When it comes to safety for workers, it is more of a dynamic work. Respondents 1, 2 and 3 are working with safety for workers in their terminals, ensuring the right safety equipment is worn and following up accidents within the operations. Workers in respondent 1 are connected to a system that’s detects if the worker is in an accident. This improves the safety for individuals working alone in the terminals since in the case of an accidents, that information reaches a supervisor. Therefore, the accident can be noticed by somebody else and actions can be taken (Respondent 1).

General for all port terminals we were in contact with the importance of safety and security for workers were of high importance. The rules and regulations for working conditions in Sweden is quite strict compared to other countries. Still the work for working conditions is a dynamic work where both companies and employes needs to continuously work to improve

their working environment. This is ensured by The Swedish Work Environment Authority(arbetsmiljöverket) and regulation paper AFS 2001:1, which regulates all companies and employes responsibility for the working environment(AFS 2001:1).

When it comes to safety and ensuring the quality of goods in terminals, it varies between terminals and the types of cargo. Cargo units such as containers can only by inspected from the outside and same with semitrailers, but general cargo and bulk cargo can be inspected since they are more transported more open. The terminals work with quality checks manually with the assistance of a digital system for trackability of the unit. Therefore, human behavior comes into play with stress, personality, and other factors. The trackability of the cargo which is manually made by scanning cargo is one way of increasing the safety of the cargo and it gives the cargo owners a better understanding of where the cargo is. According to respondent 1 and respondent 2, the cargo is manually handled by different types of vehicles in the terminals. Damages caused by accidents or handling are investigated but some damages are linked to human behavior which can be hard eliminated.

4.2 Future solutions regarding economic sustainability in port terminals

Economic sustainability is essential for all businesses, proactivity for digital solutions can be one way of secure future profitability. For port terminal this is even more important since they have assets consisting of sever infrastructure and superstructure investment.

4.2.1 Maintenance

Terminal work consists of a lot of equipment such cranes, forklift and other vehicles involved in the operations within the terminal. Terminal operators therefore work with maintenance to eliminate breakdowns in the operations because of unexpected events. Stops and decreased efficiency because of bad maintenance is not good, since ships plan for a certain amount of time in port and an increased time can lead to demurrage (Respondent 1).

The maintenance work consists of repairs based on a system taking factors such as time intervals and running time into consideration. The repairs and maintenance system are based on manufacturers' schedules and recommendations. Then there are emergency repairs of breakdown coming from unexpected events. Maintenance is in that term a continuous task, that terminal operators always need to have a plan for (Respondent 1).

4.2.2 Solutions with machine vision

Another system that is still in practice to improve efficiency in terminals is machine learning by using AI and cameras (machine vision) on quays and cranes. According to respondent 4 and 5, machine vision can be used for gathering data from cranes and quays but also for a general picture of the terminal (and port) to analyze the data and create a better decision basis. Although the application of machine vision is effective to create a better decision basis, the system needs around 10 000 pictures from each terminal/port. The purpose of this system is to increase efficiency and by creating better decision basis, the improved decision leads to faster handling of goods but also less exhaustion and loss of concentration from employees that are controlling the machinery which contribute to higher efficiency (Respondent 4).

As previously mentioned, one of the methods is to put 360 cameras and visualization support (cameras that can see everything around the object, i.e. 360 degrees) on the yard cranes, quays and other cranes that require a cabin. The concept can increase efficiency by helping the

person in the cabin with visual support, current progress of stacking containers is manual (the person that is controlling the crane is looking down to stack the containers, see picture below?) and the integration of 360 cameras and visualization support gives it a more accurate and efficient way to stack the containers. The support gives the user an image of the layout and it also provides sound if the stacking is wrong, the method can increase precision and efficiency of the handling in the yard/terminal (Respondent 5).

Machine vision or camera sensor linked to machine learning are possible to applicate in different ways and integrate into port terminals. It can be easier tasks such as detect people in wrong places and with wrong safety gear, but it can also provide more advance tasks such as yard planning and optimization based on the flows of goods. But the key is that it needs data to be trained on more data gives more advance predictions and more exact input. Therefore, it is needed to base the data collection on that task you want to train on. If the task consists of people more security is needed and more data and factors, but if the task is to advice decision making less security is needed since it is only some advice for decisions (Respondent 4).

4.2.3 Predictions

One of the most recurring topics when it came to AI possibilities and solutions in the future regarding improving efficiency in terminals where the idea of predicting time frames. This concept has different dimensions and one of the dimensions is a synchronization of logistics planning, it means that AI help with synchronizations of arrivals, departures and timings regarding goods, trucks, vessels etc. For example, planning how much goods (units, packages, etc) that can be ordered into terminal and the capacity that the terminal can handle at the time. Other functions of the logistic planning system are for example, predicting the space utilization and current blockage in the terminal. According to respondent 5, AI can predict the space utilization in terminals and terminals using functions such as machine vision or some kind of visualisation system It means that with machine vision, AI can analyse current images in the terminal and determine the current space situation. By inserting training data into AI while also using machine vision. During the day a lot of goods are transported in and out from terminals but also moved around in the facility, the AI can predict the utilization space in the terminal and if there are going to be any blockage or too many goods at one place. AI predicts the insolvencies that may occur in the terminal, such as if the blockage or overstocked goods at one place can hinder future incoming goods. Predictions is a way to increase terminal efficiency by minimizing obstacles and utilizing storage space, with further training data the AI get more accurate and more efficient (Respondent 4).

4.2.4 Economic challenges

AI is a relative new concept to the terminal business and there are ways that it can increase efficacy and effectiveness in terminals but there are factors that are limiting the influence of AI in the business. According to respondents 4 and 5, one of the most frequent factors is the economic aspect of funding AI projects. AI development usually require funding from federal agencies or other companies but there are also the alternative of a company investing in their own development. The biggest problem regarding the economic aspect is that there is no current statistical metric or enough “proof of result” when it comes to the correlation between increase effectiveness/efficacy and AI integration. This leads to a limited amount of funding in projects and therefore less AI influence in the terminal business (Respondent 4). From the business perspective for a port terminal, one metric to measure economic sustainability is ROI. For example, how much profitability a terminal would make if an investment in AI would happen. The ROI is hard to measure when it comes to AI due to the profitability can depend on more than one factor. Respondent 5 highlights that advanced AI has high costs and

can take time to adapt/implement in port terminal operations. therefore, the financial investments in AI are limited when it comes to AI involvement in port terminal (Birken, 2022).

4.3 Limitations/barriers with AI

When it comes to limitations of AI usage, there are various factors such as economic aspects and data input aspects. As previously mentioned, both respondent 4 and respondent 5 states that the economic limitation is a relevant factor that can determine the involvement of AI in the terminal business, but another factor is the data input aspect. According to respondent 5, it refers to the amount of data input that companies put into the AI system, there must be enough parameters that are put into system, otherwise the outcome can be flawed. AI does only measure and calculate a result from the data and parameters that are given, the limitations are depending on the human factor because of the parameters that are inserted into the AI system. (Respondent 5)

Respondent 5 mention that the security and safety parameter of AI is of high importance since the more human activities AI is involved in, the amount security and safety will increase. An AI-system that is working with the focus of prediction and supporting, has less need of security and safety then a fully autonomous system that is working together with people. Therefore, there are a limitation of AI depending on the task and how the system will be used. The amount of training needed for the system can be a barrier since if the training data increases in a high degree because of security and safety. It can affect the economic and time aspects in a negative way by introducing an AI-system in a port terminal (Respondent 5).

5. DISCUSSION

In this chapter the theory and result will be discussed, the information from the literature collection will be compared with the result from the interviews and conclusion will be drawn. The discussion will consist of three parts and the first part contains a discussion of the research questions. Second part will discuss which barriers that can affect AI and the third part will consist of a method discussion.

5.1 AI influence on social sustainability in port terminals

When comparing the literature from IBM and Intel with result regarding the factors that can improve social sustainability, there are topics that both parts agree on but there are also topics that the answers and opinions where different. One part where both the theory part of this report literature from Intel and result agreed on was that machine vision with AI can increase the social sustainability (Intel, 2024a). With machine vision, the AI can increase security and quality control by analysing pictures and adapt to the situation (Intel, 2024a). Machine vision affect the safety for workers positively by having cameras and sensors that can detect if worker wear safety equipment and if there are any dangerous materials/items in the way (respondent 1). Although the interviews mentioned the economic aspect more than the social aspect and the literature from IBM and Intel focuses more on the social aspect regarding machine vision, but still mention the economic side. When interviewing respondent 1, 2 and 3, the consensus was that there where limited amount of knowledge regarding AI and it made it difficult to assess the status of AI influence on their social sustainability. Although considering both the literature from IBM and Intel with result from the respondents 1,2 and 3, it would be more realistic and easier to impact the safety and social aspect with the use of AI. This is due to that machine vision and machine hearing does not need as much data input and parameters to operate as a system that detects dangers and lack of safety equipment.

Although all the systems, the respondents 1 and 2 had not considered the possibility of using machine vision before the interview but were interested in the concept. Comparing it with IBM and Intel, the research showed that in a simulation with machine vision gave advantages to a terminal but there was no concrete evidence on that the concept worked in practice and increased social sustainability (Intel, 2024). In general, the AI concept is still new in the terminal business and the evidence were clearer during the interviews and it appeared that the terminals had a limited number of practical experiences with AI. It was also evidential that the sources were intended for people in the AI business and also written by AI experts. Therefore, the respondents 1 and 2 found it difficult to answers certain question. Due to the different fields between AI and terminal businesses, understandably it was difficult for all terminals to be totally transparent with the use and ambition with AI because the nuance of AI in the terminal business.

However, the literature from IBM and Intel had more compatibility with the interview result from the AI consultant companies (respondent 4 and respondent 5). Comparing the information from both Intel and IBM with the result, it showed higher common thoughts and the future possibilities with terminal usage with AI. The consultants were highly knowledgeable in AI but also in logistic/terminal business and therefore it was easier to find common ground. The facts from Intel and the answers/result were ha similar and therefore we found the ambitions and practises reasonable such as machine vision, using sensors and cameras to analyse data to increase both safety and efficiency terminals. Respondent 4 described a project “they” worked with regarding AI usage in terminal(sensors) and the result showed an increased level of efficiency and further discussion also showed that AI has the

possibility to increase safety. Therefore, the information from the sources IBM and Intel was relevant in the case of future possibilities and the result also showed potential of further involvement to increase social sustainability.

Machine hearing is also a concept to increase the safety on equipment by detecting anomalies and notifying staff (Carly Sygrove, 2024). Although, according to our study, there are currently no practical evidence in port terminals and therefore an inconclusive method of impacting the social sustainability in the future. According to respondent 4, sound analyses are nothing new to the market, it has been used in different areas but not integrated with AI in a high degree.

5.2 AI influence on economic sustainability in port terminals

When comparing the literature from IBM and Intel with the result, the main systems economic aspect could be impacted by are machine vision., sensors and a general ability to analyse data to make predictions. IBM and Intel do not mention “predictions” to increase the efficiency and economic sustainability compared to the result. According to respondent 4 and 5, the most logical method to increase effectiveness is to use “predictions”, it also showed to be the easiest way to implement AI usage in terminal in the sense of “how difficult it is to implement” and how much it will increase efficiency. Although, according to Intel and IBM, port terminals focus more on AI development regarding terminal handling such as machine vision than predicting arrival and departure timelapses. A correlation between machine vision development and “predictions” using could be found when comparing the result with the literature but it is still no concrete evidence that it works in practice (Intel, 2024).

The correlation is that the machine vision can provide data input to the AI to make more accurate predictions and use space utilization to increase efficiency, combining the function of machine vision and sensors with “predictions” to increase accuracy and effectiveness. According to respondent 4, machine vision system can provide pictures of the layout of the terminal and analyse the pictures/data of the terminal and sensors detect what spaces are available, thereafter provide space utilization recommendations. Using the data/analysis from the AI machine vision system, sensors, and the function of predicting arrival/departure times (using data from previous experience), it could be easier to predict which spaces/places that are available in the terminal or if there are any obstacles in the way. The system would increase the efficacy by effectively find storage for incoming/outgoing goods in the terminal and make it easier for storage planning. Further development could give the possibility to use space utilization and “predictions” to predict the amount of volume that the terminal can handle at different times, the planning of volume of goods would be easier for both all actors in the process.

5.2.1 Another economic sustainability aspect (risk or reward)

The main AI systems/tools that can have an influence on the economic sustainability in terminals are the “prediction” system and machine vision. There are yet any concrete evidence that shows a functional combination both systems, but separately the system has a higher possibility of being in practice. Both systems would increase efficiency be moving goods faster in and out of the terminal but also planning accuracy, this will reduce long-term cost due to the AI are using machine learning to adapt find a better way to solve the problem.

Although, the AI functions will reduce costs in the long-term, the short-term investment of AI technology is a challenge/barrier for terminals. The result showed that the investment in AI is expensive due to the advanced technology and there is not enough AI usage in practice to

confidently invest. The risk of investing a large amount of capital and if the system fails, the economic consequences could affect the terminal in a negative way. Therefore, the limited amount of usage in terminals.

Accordingly, there are two perspectives to use AI to increase economic sustainability. The first perspective is to risk an investment in AI for a long-term way to potentially reduce costs and have higher efficient handling system. The advantage is potentially being more efficient than other terminals and save money before AI technology become more expensive with more evidence, but the disadvantage is the risk of system does not function and potentially resulting in capital loss. This is of importance since AI needs training and time; therefore, the system needs some time to be put into work. The second perspective is to wait for more practical evidence and analyse how other terminals implement AI. The advantage is eliminating the risk of capital loss and slowly adapt to the development and increase economic sustainability gradually, but the disadvantage is that the investment in AI technology can increase due to more evidence and therefore risk more expensive investments. Another risk is that several terminals may fall behind the AI technology trend and have it harder to compete. There are advantages and disadvantages with both alternatives.

5.3 Areas where AI can influence port terminals

When analysing and drawing conclusion from both the sources in the theory chapter and result, one of the more logical areas of AI are space utilization in port terminals (both in the yard and terminal facility) with the use of machine vision and sensors. According to respondent 4, machine vision and sensors are a way to forecast space utilization by using data input to measure/see occupation status on the storage places in the terminal but also analysing data to predict/see processing time of goods. Another way of AI influence of space utilization in terminal facility is the ability to use predictions such predicting arrival and departure times of goods in the terminal by using old data and machine learning to improve the accuracy.

AI can also influence the safety in terminal facility by using machine vision, machine hearing and sensors such as cameras to analyse danger concerns for workers and machines (Intel, 2024). Examples of this are cameras on equipment that can provide visuals safety for workers and the sensors provide a sound safety by detecting nearby dangers for workers. Other safety concerns for terminal workers are the maintenance and condition of equipment. One solution is AI machine hearing that can detect the anomalies in machines/equipment. Machine hearing detect anomalies in the equipment by using sound analyses. According to respondent 4 and 5, machine hearing can detect abnormal sound from the machine and notify staff. To achieve this, data input and parameters such as regular and irregular sounds need to be in the system.

Another area is in the port yard and the safety on the equipment. AI can influence the safety for workers and the efficacy of the operations by using functions such as machine vision (Intel, 2024). Respondent 4 mentioned that machine vision such as 360 cameras on certain equipment(cranes) could increase efficiency by helping manual placement of goods (often container) through having visuals, recommendations, and accuracy placement from the machine vision. The cameras gather data, which the AI then analyses and offer recommendations to the staff. This enables them to place goods more efficiently and accurately.

5.4 Barriers for AI

According to Unctad(United Nations, 2022)one big challenge for ports and terminals is the risk of cyberattacks. Increased amount of digital complex infrastructure and informatic flows, will affect the risk and impact of cyberattacks. The risk of cyberattacks is also wider than the single operator since port are an importance part of the whole country's economy. Therefore, if there are new and complex IT-systems in port terminals there are also high interest of working against cyberthreats. This risk of cyberattacks can therefore be a barrier for new investments in port terminals, both the increased cost of high digital security and effect of an cyberattack. Both this is not something that are unique for this branch, it is an important topic for all types of branches. Regarding security, AI also has a level of uncertainty since there are a bit unclear with the responsibility part of the possible effects of AI. Who is taking the responsibility of a vehicle operating by AI-system when it is part of accidents. This can be barrier since no one wants to take the responsibility of something when it goes wrong.

Data input or available data for AI is the base of its working, lack of data can therefore be a limitation. But the amount of data needed is connected to the task AI are aimed to perform. Fully autonomy vehicles operated together with people need more data and training then an AI-system for predictions of the ETA for port calls. But of course, the more data available for the task will affect the precision of the system in a positive way.

The economic part of different AI-solutions in port terminal can be a bit of an uncertainty, examples of questions linked to the uncertainty regarding AI-solutions can be what the costs and effects of the AI-solution will be. Because of this it can be hard to convince shareholders in investing in something without an exact number of the increased efficacy of the investment as an example. If the solution also is expensive and this uncertainty regarding the exact effects still exits, it is risk that the AI-solution never gets a chance. One more aspect of this is the time, the starting time for AI can be critical aspect since they need time and training to operate in the way you expect them to do.

But even if there are some uncertainties and barriers for AI-solutions of port terminals. Still the future will increase to find solutions better, securer, efficient, and cheaper. Therefore, it can be smart to wait but waiting too long with investments in of AI-solutions are with a risk of be after your competition. There is also a big risk of getting behind on this, since there is an adapting period of AI-solutions. The first mover can therefor get an advantage, which the competition can have problems to compete whit when it comes to utilization, effectively, safety and resource allocation.

5.5 Method discussion

In this report, the gathering of the empirical data was trough a qualitative method with semi-structured interviews. In this method discussion, an analysis of the advantages and disadvantages with the qualitative method.

The first part of the empirical data gathering consisted of a literature search of peer-reviewed and scientific articles. The advantages are that it gives a broad overview of previous reports and research of the topic. It gives a foundation of knowledge of the subject and relevant information of current situations. The disadvantages are the limited amount of specific data regarding the subject. The subject is new to the port business and finding relevant data can be limited. Another disadvantage is that because of the limited data available, the bias to choosing the literature could affect the validation and reliability of the report. Validation refers to how well the study participants mirror the accuracy of the findings and if it

represents similar participants outside the study. Reliability refers to how consistent and easy the measure or outcome is if the study would be replicated again. To reassure the validation and reliability of the report, certain criteria were applied. The criteria consisted of, only peer-reviewed articles, relevant company research and articles, authenticity, and reliability of the author. These criteria were vital due to most of the sources were gathered from the internet. Exceptions to the criteria were literature from reliable books at Chalmers Library.

Interviews was based on participants that was interested of being interviewed, terminals and consultations with other experiences but no interested of being interviewed was in that sense out of the scope for this report. But still our interviews were of relevant character for this work and contributed to this report. The strategy for the interviews was to send the questions beforehand to the participants, so there was an opportunity to prepare answers for the questions. There was also experience made from each session and the first session would probably better with the experience gained for each session if it was redone.

The limitation of this work to Sweden, could have affected the results in the term of the limited amount of big port terminals. With a wider selection of port terminals, we would most likely find some terminals with other views and more adaptions of AI up and running. Which could result to another conclusion and real examples of AI in port terminals.

6. CONCLUSION

In conclusion, AI can improve social sustainability in a port terminal in the future by using systems such as machine vision and sensors. The machine vision and sensors increase the safety for workers applying sensors and visual assist to equipment and therefore minimizing risk of injuries and accidents in port terminals. In terms of economic sustainability, AI can enhance it by using machine visions, sensors, and “predictions”. The machine vision and sensors will assist with space utilization in the terminal facility by detecting available space and the most optimal space for certain goods. Predictions will help the accuracy the forecast of the arriving and departing goods in the terminal facility. Enhancing the efficiency of in port terminal will lead to costs reduction and revenue increase.

There are limitations or barriers that affect the development and progress of AI involvement in port terminals. The two main aspects are the economic barrier and available data/parameters. There needs to be enough investment to make AI functions in port terminals and there also needs to be enough data/parameters for AI to be effective.

But there are some restrictions and barriers of AI-solutions, such as cyberattacks and responsibility of the AI. Specifically with an increased risk of cyberattacks, using more AI-solutions can be a risky strategy for the terminal’s resilience for IT-threats. The responsibility part can also be an issue for investments in AI-solutions, entering new areas with the lack of knowledge can lead to caution for investors.

6.1 Recommendations for future research

This report could have expanded towards other actors within the port terminal business in Sweden since there are both bigger and smaller actors in business. Another aspect worth investigating is the different types of decision makers, such as the IT-department in port terminals or the economic department to get a broader perspective into the port terminal business.

More research needs to be done to have concrete evidence and statistics that AI can improve social and economic sustainability in port terminals. If there were more direct evidence and examples of the effects of AI in port terminals, more applications and solutions would have been done. Lastly, we recommend that this research should be replicated but in a couple of years due to the limited amount of usage of AI in port terminals.

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