



CHALMERS
UNIVERSITY OF TECHNOLOGY



Coordinated approach for port operation and vessel traffic scheduling in Roll-on Roll-off (Ro-Ro) terminals: a case from Sweden

Master's thesis in Master's Programme in Maritime Management

AVINASH GUPTA

DEPARTMENT OF MECHANICS AND MARITIME SCIENCES

CHALMERS UNIVERSITY OF TECHNOLOGY

Gothenburg, Sweden 2025
www.chalmers.se

Master's thesis 2025

Coordinated approach for port operation and vessel traffic scheduling in Roll-on Roll-off (Ro-Ro) terminals: a case from Sweden

AVINASH GUPTA



CHALMERS
UNIVERSITY OF TECHNOLOGY

Department of Mechanics and maritime Sciences
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden, 2025

Coordinated approach for port operation and vessel traffic scheduling in Roll-on Roll-off (Ro-Ro) terminals: a case from Sweden

Master's thesis in Master's Programme in Maritime Management

© AVINASH GUPTA, 2025

Supervisor: Associate Prof. Wengang Mao, Department of Mechanics and maritime Sciences

Examiner: Associate Prof. Henrik Ringsberg, Department of Mechanics and maritime Sciences

Department of Mechanics and maritime Sciences

Division of Maritime Studies

Chalmers University of Technology

SE - 412 96 Gothenburg

Telephone + 46 (0)31-772 1000

Abstract

Shipping is the foundation of international business, includes various stakeholders such as terminal, shipping lines, cargo owners, and port authority. These stakeholders are important for the efficient supply chain and logistics operation. One of the stakeholders that is terminal act as a connecting entity among all other stakeholders. Therefore, the terminal operation efficiency depends on the coordination between terminal, shipping line and cargo owner. The thesis explores on finding the challenges causing disruption in the Ro-Ro terminal operation and the current digital technologies used to reduce these challenges. The methodology comprises of a deductive research approach, that has been applied to develop the Theoretical Framework. The study emphasized to collect data through qualitative research method from a single case study that includes semi-structured interviews. The data collection from interviews were conducted with two terminal managers and one ship's cargo officer. The themes from literature review were highlighted as challenges in cargo operation, vessel scheduling and adoption of DT technology in the thesis. The findings of the thesis showed that the digital technologies were present in the terminal operation, but the full utilization could not be achieved. The thesis provided the useful insights on using DT simulation model and requires coordination between different stakeholders to enhance port operational efficiency.

Keywords: Ro-Ro terminal, Ships Estimated Time of Arrival (ETA), Port Operation, Port Efficiency, Port Digital Twin, Automatic Identification System (AIS), Vessel's Turnaround Time

Acknowledgements

This master's thesis has been successfully conducted as a part of the department of Mechanics and Maritime Science withing the Maritime management program (MPMAR). The thesis was conducted during the spring of 2025 at Chalmer's University of Technology, Gothenburg.

First, I would like to express my gratitude to my supervisor and examiner in the journey of conducting the master's thesis as Supervisor: Associate Prof. Wengang Mao and Examiner: Associate Prof. Henrik Ringsberg Department of Mechanics and maritime Sciences. I would like to thank you both for the guidance and showing trust throughout the master's thesis project. Also, I would thank the Henrik for arranging meetings with the John Wikstrom of Gothenburg Ro-Ro terminal. For conducting the interview with the participants of Gothenburg Ro-Ro terminal, I would personally thank John and helped me throughout the thesis project. Thanks to all as I made new connections and learned new things about Ro-Ro terminal, which would be very interesting for my future endeavours.

I would like to thank all the interviewees who participated for the interview and given their precious time for my thesis project. Their participation has been highly appreciated.

I would like to thank my family and friends for been the supporting pillar and motivated all along the thesis project. Their support always been my strength to excel to finish my thesis.

I hope that this master thesis can provide valuable knowledge and input for the future opportunities within the maritime industry.

Thank you!

Gothenburg, 2025

AVINASH GUPTA

Table of Contents

Chapter 1: Introduction.....	1
1.1 Background.....	1
1.2 Research Purpose and Research Questions.....	2
1.3 Delimitations.....	2
1.4 Report outline.....	3
Chapter 2: Theoretical Framework.....	4
2.1 Automatic Identification System (AIS)	4
2.2 Estimated Time of Arrival (ETA) of Ship.....	6
2.3 Ro-Ro Port Terminals.....	7
2.4 Time-cost Efficiency in Port Operations	9
2.4.1 Digital Twin in Maritime Port Operations.....	10
2.4.2 Tools and Frameworks for Terminal Efficiency.....	11
2.5 Vessel Turnaround Time.....	13
Chapter 3: Methodology.....	14
3.1 Literature review	14
3.2 Case Study.....	17
3.3 Data Collection – Interviews.....	18
3.4 Data Analysis.....	20
Chapter 4: Results and Analysis.....	21
4.1 Vessel Scheduling in Ro-Ro terminal	21
4.2 Planning of Cargo operations at Ro-Ro terminal.....	22
4.2.1 Cargo Arrival/departure process in Ro-Ro terminal.....	23
4.2.2 Cargo operation time.....	23
4.2.3 Cargo Dwell Time.....	24
4.3 Challenges in planning of cargo operations at Ro-Ro terminal...	25
4.4 Digital technologies in Ro-Ro port operation.....	26
Chapter 5: Discussion.....	29
5.1 Vessel Scheduling in Ro-Ro terminal	29
5.2 Planning of Cargo operations at Ro-Ro terminal.....	29

5.3 Challenges in planning of cargo operations at Ro-Ro terminal...	30
5.4 Digital technologies in Ro-Ro port operation	31
5.5 Methodological Discussion.....	31
Chapter 6: Conclusion.....	33
6.1 Managerial implications.....	33
6.2 Further research suggestions.....	34
References	35
Appendix.....	40

List of Figures

Figure 1: Overview of AIS system	4
Figure 2: Ro-Ro Terminal Cargo Process	8
Figure 3: Snowballing technique	16

List of Tables

Table 1: Features of AIS data and description of transmitted messages	5
Table 2: Inclusion/Exclusion Criteria	15
Table 3: Initial Keywords Search	15
Table 4: The vessel arrival/departure time schedule in Gothenburg Ro-Ro terminal from Immingham Port	18
Table 5: List of Interview Respondents	19

List of Abbreviations

Abbreviations	Description
UNCTAD	United Nations conference trade and development
IMO	International Maritime Organisation
GHG	Greenhouse gas
EPCIS	Electronic product code information service
Ro-Ro	Roll-on Roll-off
ETA	Estimated time of arrival
AIS	Automatic Identification System
DT	Digital Twin
PCS	Port Community System
IOT	Internet of things
DES	Discrete event simulation
POMS	Port operation management system
AGV	Automated guided vehicle
SLAP	Storage location assignment problem
DSS	Decision support system
AACO	Adaptive ant colony optimization algorithm
GPS	Global Positioning system
VHF	Very high frequency
GT	Gross tonnages
MMSI	Maritime Mobile Service Identity
SOG	Speed over ground
COG	Course over ground
ATA	Actual time of arrival
KPI	Key performance indicator
OCR	Optical character recognition
DFDS	Det Forenede Dampskibs-Selskab
CLdN	Compagnie Luxembourgeoise de Navigation

1. Introduction

This chapter of the MSc thesis represents the Background giving insights about the thesis topic in a systematic approach. Gives an overview of the thesis as why this research subject is discussed and need for that. Furthermore, this chapter outline the purpose and research question of the MSc thesis. With the inclusion of delimitations and subsequently followed by the report outline in the end.

1.1 Background

Shipping is the foundation of international business. It is important in terms of Globalization which is the core of logistics and supply chain. United Nations conference trade and development states that over 80% of international trade by volume is carried by sea. With the increasing demand for the commodities, the global maritime trade has increased by 2.4% in 2023 (UNCTAD, 2024).

Ports key performance indicators which include (a) number of operators handling the cargo operations, (b) berth occupancy, (c) capital equipment expenditure per ton of cargo and (d) ships turnaround time were described for a port operation (Notteboom et al., 2021a). This indicator performance is very important to be measured for maritime operations to terminal (port) and hinterland operations (Notteboom et al., 2021a). Key challenges include ship delays like long waiting times at anchorage because of port congestion will lack in berthing on time or long ship turnaround time can impact the port operations and its efficiency (Shetty et al., 2021).

Similarly, Sauri et al., (2012) critically examined that when the cargo on trucks and trailers have longer dwell time for loading or unloading at the port for a ship and other disturbances, will impact the port operation and its efficiency. Academically numerous research papers were published in optimizing port operation suggesting mathematical models, algorithms and frameworks. One such Framework were formulated for logistic operations of trailers at the port terminal using EPCIS (Electronic product code information service) standards and improves the port management efficiency (Ringsberg and Lumsden, 2016).

According to Eurostat, around 58.2% of total European maritime transport moved in short sea shipping which includes Container and Ro-Ro ships (Eurostat, 2022). “Roll-on/Roll-off (Ro-Ro) is when cargo is ‘rolled on or rolled off’ from and to a ship. The vessels are designed to carry cargo that is wheeled, such as cars, trucks, railroad and project cargo on trailers that are driven on and off the ship on their own wheels or by using a truck” (Henessey et al., 2020).

As Ro-Ro shipping plays an important role in fast cargo handling and enhances supply chain efficiency in the intermodal transport (Christodoulou et al., 2019). For stakeholders, the Ro-Ro terminal operation should be efficient in vessel scheduling and cargo operations (Sauri et al., 2012). Paulauskas and Vytaitas, (2020), used mathematical and statistical data method to evaluate the estimated time of arrival of Ro-Ro ships in the port, considering the delay factors and optimising the operation.

Despite number of research shown optimizing one measure, there is still a gap in the published literature in combining two measures and evaluating overall efficiency for the shipping industry. From an industrial perspective, poor coordination between the vessel traffic management and the port operations may result with the challenges. These challenges have been discussed such as port congestion, waiting time at anchorage, unavailability of berth terminal, longer loading and unloading time. These challenges may highly impact in port efficiency. However, an efficient vessel scheduling using (AIS) data and coordinated port operations in Ro-Ro terminals will be cost effective for the shipping companies.

1.2 Research Purpose and Research Questions

The purpose of the thesis is to explore use of a coordinated approach for port operation and vessel traffic scheduling in Roll-on/Roll-off (Ro-Ro) terminal to optimize the terminal efficiency. The thesis focuses on finding the challenges and current operational activities information in a Ro-Ro terminal.

- How can the operational efficiency of a Ro-Ro terminal be optimized in complex loading and discharging operations?
- How can a Ro-Ro terminal optimize the operational efficiency through the adoption of digital technologies?

Furthermore, the thesis aims on highlighting the adoption of digital technologies like DT to optimize the terminal efficiency and reduce inefficiencies.

1.3 Delimitations

This thesis research is limited to pre-study of Gothenburg Ro-Ro terminal and does not include any other port. The thesis is also limited to qualitative research method includes literature review and interviews. The research is limited to interviewees perspective of operational activities, challenges and digital technologies. However, participants from shipping line and customers not included for the collecting data through interviews. The interviews were conducted with close collaboration of port operators or manager of the Goteborg Ro-Ro terminal, Gothenburg and cargo officer of DFDS Ro-Ro ship arriving and departing the Gothenburg Ro-Ro terminal. The thesis finding was limited to the sea-side interface that is terminal operations include vessel scheduling and cargo operations. Thus, not included the landside interface that includes the hinterland operation. The thesis was centred on exploring the Ro-Ro terminal operation within Sweden region and not included other countries port region. The thesis was limited to collect interview data and not included any quantitative statistical data to calculate the efficiency of the terminal operation. As collection of statistical data and real-time data was not accessible due to reason of time constraint for field experiments and confidentiality of the data. The thesis also does not include the type of cargo and analysis of their operation within the terminal premises. The thesis was limited to examine the use of digital technologies in terminal operation and exclude developing new digital tools.

1.4 Report outline

The master's thesis outline is followed as: chapter 1 introduces the reader about background, research purpose, research question and delimitations of the topic highlighting the need for the thesis research. Then chapter 2 outlines the literature review from various research papers showing the area of research from topics and theories involves for the thesis. After this, chapter 3 includes the methodology section that provides the reader of the design and data collection method and how the data has been analysed in the study. Chapter 4 provides the results and analysis from the interview data and the literature review that test the hypothesis of the theory. Chapter 5 presents the discussion on the topics of results followed by chapter 6 that includes the conclusion of the study report and presenting the future implications. In the end appendix and references are included for the reader.

2 Theoretical Framework

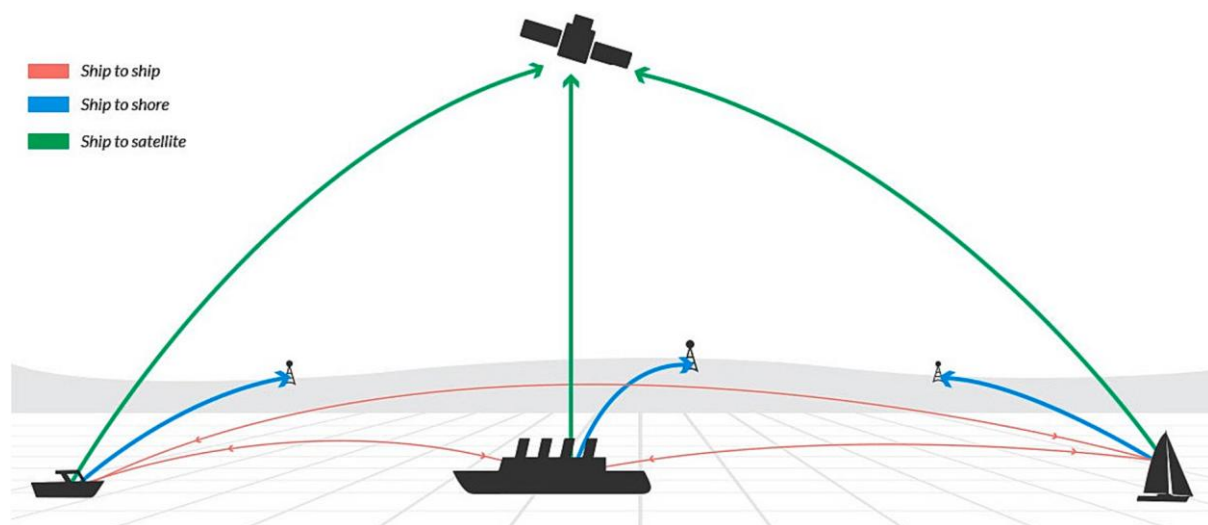
This chapter introduces the necessary Theoretical foundation related with the topic. It has been structured in six sections and further those sections were described in subsections. Sections and subsections such as Ro-Ro port terminals, Cargo logistics operation in a Ro-Ro terminal, Time-cost efficiency of Port operation, Digital Twin in Maritime Port operation, Tools and frameworks for terminal efficiency, Vessel turnaround time, Automatic identification system (AIS), Estimated time of arrival (ETA) of ship are included and presented.

2.1 Automatic Identification System (AIS)

The AIS is a digital system used to track the vessels identification and real-time position in maritime navigation (Emmens et al., 2021). In the past, AIS were usually used for the purpose to avoid ship collision in dense traffic, protecting the marine environment, and overall surveillance to improve ship safety (Harati-Mokhtari et al., 2007). In addition, Svanberg et al., (2019) identified in the study that using the AIS data can have economic benefits to stakeholders including shipping companies, shippers, fourth-party logistics companies and maritime port.

AIS systems include data and information which is communicated between ship to ship, from ship to shore and shore to ship, see Figure 1 (Yang et al., 2024, p. 2). The information is transmitted through technology called Global Positioning System (GPS) at Very High Frequency (VHF) radio wavelength, but coverage was limited to 10-20 nautical miles (Iyer, 2013). Yang et al. (2019) states that after 2008, it is now possible to receive AIS data anywhere in the world as satellites are equipped with AIS receivers, making transmission easier from ship AIS transponders. AIS data can easily be collected from websites such as (Marine Traffic, Spire, Space Quest, Elane, AISHub, and Vessel Finder), that provide open database access to stakeholders and companies through API available in JSON, XML, and CSV format.

Figure 1: Overview of AIS System



Note: AIS data transmission system (Yang et al., 2024, p. 2)

According to Safety of Life at sea (SOLAS) convention, it is mandatory for all vessels above 300 gross tonnages (GT) involved in international voyages and all passenger ships, to install an AIS transponder onboard the vessel (Yang et al., 2024). The AIS data is classified in two groups (Classes A and B), (Yang et al., 2019) described as follows-

(a). Class A - Information transmitted by ship's AIS transponder consist of 3 types, that are static, dynamic and voyage related information. Further all three types are divided into 11 different fields as shown in Table 1 (Yang et al., 2019, p. 758).

Table 1: Features of AIS data and description of transmitted messages

Data	Types	Transmission time interval	Information Transmitted
AIS identity and location	Static	6 min	Maritime Mobile Service Identity (MMSI) and location of AIS system antenna onboard
Ship Identity			Ship name, IMO number, type, and call sign
Ship Size			Lenth and Beam
Ship Position	Dynamic	2-10 second (depends on ship's speed while sailing), 3 min at anchor	Latitude and Longitude
Ship Speed (SOG, COG)			current speed in Knots
Rate of turn			degrees per minute
Navigation direction			Heading of the ship
Time stamp			For the position in UTC time
Navigation status			underway using engines, at anchor, moored
Destination and ETA	Voyage related	6 min	Destination port and estimated time of arrival
Draught			Depth below ship

Note: AIS data and description of information (Adopted and modified from Yang et al., 2019, p. 758)

(b). Class B – Information transmitted by ship’s AIS transponder has limited data such as IMO number, draught, destination, ETA and navigation status (Yang et al., 2019).

Lee et al. (2019) further added that there is a fourth type of AIS data. The transmitted information contains safety-related data that includes free format, short text messages (manually entered) broadcasted to all ships and shore stations. Additionally, Lee et al. (2019) stated that static data is entered into the system on installation while voyage related data is manually entered and updated during the voyage by duty officer. For the dynamic data, it gets automatically updated continuously from ship sensors installed onboard a ship.

Yang et al. (2024) highlighted the quality issues related AIS data such as inconsistent data formats or errors when entering data manually, erroneous or unreliable automatic data generated from sensors, duplication or inaccuracy of data. Therefore, it is important to filter duplicate or inaccurate data as suggested by (Yang et al., 2019). AIS systems should always be in operation while underway or at anchor, in extreme scenario there might be unintentionally switching off the system by ship’ crew leading to errors. Additionally, AIS data can pose a threat of cyber security or pirates, that can track ship position breaching safety and security of ship’s crew (Yang et al., 2024). AIS is used for the route optimization of vessels, managing vessel traffic and scheduling problem, predicting Estimated Time of Arrival (ETA) of ships in enhancing the logistic operation (Yang et al., 2019).

2.2 Estimated time of Arrival (ETA) of ship

Veenstra and Harmelink (2021) states that in a port operation, ETA of ship information provided by shipping companies is essential to plan vessel scheduling in advance. Estimated time of arrival (ETA) is the expected time of a vessel to arrive at the destination port terminal and Actual time of arrival (ATA) is the actual time a ship arrives at port (Evmides et al., 2024). The ship shares the ETA information to port harbour master and other stakeholders such as charterer, vessel agent, and shipping company vessel manager. According to Veenstra and Harmelink (2021), the first ETA is sent within 12-24 hour before actual arriving the port and the final actual ATA is emitted shortly before reaching the port. Furthermore, the ship arrival process has been described by Veenstra and Harmelink (2021) as follows-

- (a). ship arrives at the destination port
- (b). ship might spend time at anchorage depends on tide or berth availability
- (c). Pilot arrives and goes onboard the ship who guides the ship towards the terminal
- (d). then ship moored at the designated berth

According to Evmides et al. (2024), suggested that terminal operators and stakeholders can make efficient decision to improve the terminal operations through accurate ETA predictions. Evmides et al. (2024) also highlighted the uncertainty in ship arrival times that can cause delays and port congestion interrupting the entire port operation and supply chain. Further explained by Evmides et al. (2024) that port management needs to adjust the berth allocation plan in the event of ship’s late arrival to the port and can impact in rescheduling of other ship causing significant decrease in port performance.

Through quantitatively analysing in the study, Emmens et al. (2021) identified promise of using AIS data for optimizing the port operation, management of supply chains and predicting accurate ETA of ships. Further, described that AIS data is useful in predicting the ship arrival pattern and help in adjusting the cargo logistics accordingly. According to Bi et al. (2024), Historical AIS data can be used in ship trajectory prediction while enhancing the maritime efficiency and reducing navigational risks. Currently, Artificial Intelligence and different types of machine learning algorithms techniques discussed by (Bi et al., 2024, Durlik et al., 2023, Evmides et al., 2024, Park et al., 2021) is being used to build predictive models based on real-time AIS data for ships ETA.

Durlik et al. (2023) further discussed the Artificial Intelligence, Internet of things, Blockchain and big data and the use of big data analytics in maritime industry. As AIS data is in enormous amount, analysing the data using Machine Learning models can improve decision-making process and enhance port operations by optimizing vessel scheduling, improve berth allocation and reduce turnaround times (Durlik et al., 2023).

2.3 Ro-Ro Port Terminals

Ports are characterized by their performance and determination which shows the growth in global trade (Kishore et al., 2024). Ports consist of different types of specialized terminals to handle the different types of cargo. These terminals are categorized as: (a) General cargo terminals – includes beak bulk terminals, neo bulk terminals and Ro-Ro terminals., (b) Bulk cargo terminals – includes liquid (oil and gas) terminals and dry bulk terminals (e.g. coal, grain, scrap)., (c) Passenger terminals – includes ROPAX and cruise terminal (Notteboom et al., 2021). It includes port operations such as logistics, storage and warehousing, transfer or loading and unloading of cargo from port to ship and ship to shore in a time schedule (Lun et al., 2010). A port or terminal comprises of various stakeholders such as truck operators, stevedores, port authorities, shipping companies, cargo coordinator, shipping agents, customs (Bassan et al., 2007). Maritime Port Operations is important for global supply chain by connecting the sea transportation with land transportation. Even very less stevedores are required to drive the trucks and trailers for loading and unloading process at the terminal and so considered an efficient logistics (Morales-Fusco et al., 2010).

A Ro-Ro terminal is defined as to accommodate a specific type of ship i.e. Ro-Ro ship. Ro-Ro terminal has the capacity to facilitate only wheeled cargo which includes large open areas for storage, specialized platforms for smooth loading and discharging of trucks, semi-trailers, cars and buses (Morales-Fusco et al., 2010a). Ro-Ro terminal can streamline the loading and discharging of wheeled cargo without the need for lifting equipment like cranes which is essential in the container terminal (Morales-Fusco et al., 2010). This makes the ideal choice for many stakeholders and carriers to transport the cargo as fast as possible while it reduces the port time in the cargo operation (Christodoulou et al., 2019).

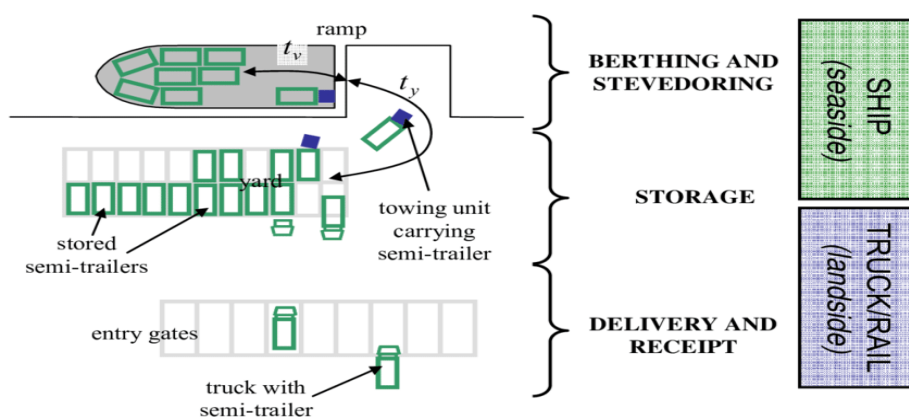
Cargo operations start once the vessel is berthed in the terminal and unloading process starts as per an unloading plan and then stored or transferred to the yard area. Once all the cargo is unloaded from the ship then the loading of import cargo takes place according to stowage plan (Gharehgozli et al., 2016). According to Dias et al. (2010), Ro-Ro terminal function as a link between sea and land, which is considered by shipping stakeholders for short sea shipping and

fast logistic operation. Morales-Fusco et al. (2010) states that dwell time in Ro-Ro shipping is very less thus makes it an ideal choice for cargo owners.

In a Ro-Ro terminal the cargo operations start with Vehicle (cargo) unloading and is carried by stevedores (drives the vehicle) from ships platform through ramps to the planned storage (yard) area as per cargo allocation plan (Iannone et al., 2016). After completion of unloading process, the loading of vehicle takes place as per stowage plan driven from the storage area to the ships platform and secured properly (Iannone et al., 2016). Research by Iannone et al. (2016) had described different terminal operations such as ship arrival and berthing in the port, vehicle unloading and loading from ship, vehicle parking in the yard area. And the variabilities were also discussed such as ship arrival and departure time, cargo handling time, transportation time in the terminal and handling errors by workers.

Sauri et al. (2012) described the similar process of loading and unloading for cargo operation. Although Sauri et al. (2012) added that semitrailers are generally loaded first by stevedoring team and then passenger vehicles, trucks, busses and cars are loaded by their own drivers. For the unloading process the vehicle driven by their own drivers unloaded first and leaves the terminal exit gates directly and then later semitrailers, vehicles to be stored at the yard storage area are unloaded by stevedoring team. Morales-Fusco et al. (2010) calculated the stevedoring time and analysed that it varies with different type of cargo, which affects the loading and unloading time. The author explained that time taken by stevedores for handling semi-trailers - firstly time spend in travelling in the ship platform, secondly time spent in manoeuvring in the yard for storage of cargo. Cargo process in a Ro-Ro terminal has three subsystems such as berthing and stevedoring, storage and delivery and receipt. These three subsystems are part of two system ship (seaside) and truck/rail (landside) of cargo process, see Figure 2 (Morales-Fusco et al., 2010, p. 699).

Figure 2: Ro-Ro terminal Cargo Process (Morales-Fusco et al., 2010, p. 699)



2.4 Time-cost efficiency in Port operations

In a competitive environment, a port must provide the cost-effective services in handling of vessels and cargo. While looking at the quality service of a port operation, port has different options to consider for cost incurred such as cargo loading and discharging time and the cost of the operation at the port terminal, vessel turnaround time, and time taken for cargo entering and leaving the port area (Talley, 2006). Sometimes port congestion results in waiting times of

ship and even the cargo at the port. To improve operational efficiency of a port fast loading and discharging process is required, for example a Ro-Ro vessel berthing on time and cargo is ready to be loaded and discharged as soon as possible to reduce ships turnaround time (Talley, 2006).

According to Erena et al. (2021) a technical efficiency for an organisation is to maximize the output by minimum inputs such as labour, capital expenditure, technology without wasting time or resources. This is crucial for competitive advantage, economic growth by resource optimization and has a positive environmental effect. While energy efficiency is the amount of energy utilised in services to generate output with less energy consumption (Iris and Lam, 2019). From a port and terminals perspective, energy efficiency is considered important and aims in reducing energy consumption by using eco-friendly and sustainable energy. Using of sustainable energy such as use of alternative fuels (LNG, biodiesel, hydrogen), renewable energy (Solar and wind) and electrification of terminal equipment would reduce greenhouse gas emissions (GHG) which is a direct outcome of energy efficiency (Iris and Lam, 2019). According to Iris and Lam (2019), there is a connection between port operational efficiency and port energy efficiency. Furthermore, described that shifting towards electrification of resources in a port would replace the use of fuel and added that supplying power from shore to ship while ship is berthed would reduce energy consumption and emissions, thus enhancing energy efficiency.

This is as important for a shipper and carriers to calculate the port time-related costs in choosing the right port. Also, when a ship is berthed in a port, the shipper incur cost if it stays for longer duration of cargo operation. Some of the port services includes vessels port stay which consume fuel and charged for labour usage, trucks and trailers as carriers for cargo loading and discharging incur costs. For a shipping companies' perspective, the port must work on to reduce the ship turnaround time by optimizing the port operation to achieve maximum throughput and that makes a port technically efficient (Talley, 2006).

For an efficient port operation there are some key indicators which include number of operators handling the cargo operations, berth occupancy, capital equipment expenditure per ton of cargo and ships turnaround time (Notteboom et al., 2021). According to Talley (2006) a port performance depends on the time-related costs of cargo transfer from ship to port and port to ship. According to Bassan et al. (2007) stated that "*vessel waiting time and operation time in a port terminal*" is directly related to the operational cost of a ship. This has been a longtime concern for all the shipping companies as long turnaround time in port involves high cost of operation and more energy consumption.

In the published studies, (Bucak et al., 2020, Kishore et al., 2024, Sepehri et al., 2024) have conducted a systematic literature review on the port's performance and efficiency. In their research they have found out that a lot of published research within time interval that has been conducted to optimize the logistics and port efficiency using various methods, algorithm and framework. One such framework of improving the efficiency of logistics operations in port terminals by analysing "Electronic product code information services (EPCIS)" standard (Ringsberg and Lumsden, 2016). In the research paper the author has suggested that using the (EPCIS) standard in logistics of Trailers loading and discharging in the terminal would save lots of time and cost of operation. From an industrial perspective, any improvement in the operational efficiency would be a cost effective in reducing fuel consumption and subsequently contribute to less emission.

2.4.1 Digital Twins in Maritime Port Operations

Zhou et al. (2024) defines Digital Twin (DT) as an advance technology used for virtual representation, simulating the process with real – time data of a physical system or product device. While reviewing scholarly papers, the definition of DT has been described with different interpretations, still the actual meaning remains the same. According to Neugebauer et al. (2024), a DT system has been implemented in port terminals and specifically to digitize the ports infrastructure and continuous improvement of port logistic operations, in application of Port Community Systems (PCS). Additionally, Internet of Things (IoT), Big data, simulation, mathematical modelling, optimization tools, Blockchain, and cloud computing are some of the essential digital technologies utilized in the DT process (Neugebauer et al., 2024).

Kastner et al. (2024), highlighted that in the past after covid-19, due to improper vessel scheduling and even variation in cargo volumes of supply demand caused interruption in the maritime supply chain. Eom et al. (2023) highlighted the use of DT model in a port by coordinated approach of the stakeholders such as terminal operators, pilot boats, tugboats, port authorities, shipping companies and third-party logistic carriers, cargo owners would be able to monitor and track in real – time port operations. With the use of real-time simulation (DT), prediction and decision – making in port operation would eliminate bottlenecks and port congestion and reduce energy consumption, thus enhancing port efficiency and improve performance (Eom et al., 2023). Zhou et al. (2021) stated that as technology is advanced in the present time, using DT simulation with real-time data would solve the complex port process. Supporting the statement, Neugebauer et al. (2024) states that DT can also be beneficial for cognizance and improving the complex port process, thus enhancing the port efficiency.

Utilizing the DT technology in transforming smart maritime management, depends on one of the core features of shipping industry is to implement harmonious collaboration between machine and human (Zhou et al., 2024). Zhou et al. (2024) also described that real – time data collection, monitoring and simulation through DT platform would provide real-time operational decision making for efficient logistic and supply chain management in a port. Useful information such as big data analytics (example as AIS data), deep learning, machine learning algorithms (example as ships ETA prediction), artificial intelligence would be used in optimizing the maritime port operation. Addition to digital data, Kastner et al. (2024) identified the reasons for poor performance and suggested that analysing the historical working shift data in DT simulation would optimize terminal operations. Collecting the real-time data from ships and terminal operation such as vessel arrival time in berth scheduling, cargo allocation in the yard, cargo stowage planning, and integrating them to make schedule planning on DT platform would enhance the port efficiency (Eom et al., 2023).

2.4.2 Tools and Frameworks for Terminal Efficiency

Sauri et al. (2012) proposed a numerical framework and made a cause-and-effect diagram showing the disturbances that affect the Ro-Ro terminal operational performance and its efficiency. Disturbances such as delay in the stevedoring process and ship departure delay caused by longer stevedoring handling time are the most common findings in a Ro-Ro terminal and for that reason it is essential to evaluate the consequences for terminal performance (Sauri et al., 2012). While assessing the daily operation decision, Iannone et al. (2016) had proposed

a flexible Discrete Event Simulation (DES) model and suggested that using the simulation tool to evaluate vehicle allocation in the yard can streamline the Ro-Ro terminal performance.

Santos et al. (2018) described similar variables such as arrival/departure time were assessed using discrete event simulation (DES) models using ship characteristics and operational data for the Ro-Ro port terminal. The research analysis to evaluate the performance of Ro-Ro terminal was conducted of ships sailing between port of Leixoes, Portugal and port of Rotterdam and arriving/departing at port of Leixoes. The findings of Santos et al. (2018) showed that departure is faster than berthing process and suggested to use past data to predict the pattern of ship arrival time.

Ringsberg and Lumsden (2016) described the standardized approaches for cargo handling (semi-trailers) to improve the logistic operation in a Ro-Ro terminal. The author presented the framework using Electronic Product Code Information Services (EPCIS) standard for the logistic of import, export and transshipment of trailers in the terminal area. According to Främling et al. (2013) an EPCIS can be described as a standard specification provided by GS1 (Global Standardisation One) system used to track and trace of goods included in the supply chain process. Framework formulated by (Ringsberg and Lumsden 2016), presented an analysis of export, import and transshipment trailer logistic operation that are included in EPCIS standard and the finding showed that adoption of EPCIS standard will reduce time in the logistic operations and improve efficiency. Additionally for enhancing the logistic efficiency of cargo in the terminal would require the electronic data collection and statistical method for analysing using of EPCIS standard would be challenging in the maritime industry (Ringsberg and Lumsden 2016).

M'hand et al. (2019) highlighted that the management of logistics operation in Ro-Ro terminal could be done by using auto-ID technologies such as Barcode, Magnetic card ID and QR code on the cargo or vehicles. Using the sensors for real-time tracking would record and monitor the traffic flow, check in time and stay time of the vehicle in the Ro-Ro terminal. Although findings by M'hand et al. (2019) was in design phase and not implemented in a real Ro-Ro terminal. M'hand et al. (2019) had suggested that using technologies to gather information from real-time data would reduce the checking time and increase flow in improving overall performance of the terminal. Kafka for message broker and SQL document database used for transfer of data and collection, completes the objective to track and trace the cargo/vehicle movement in the Ro-Ro terminal.

Murgoitio et al. (2016) proposed to develop a new technological tool – Port Operation Management System (POMS), that will improve operational logistics planning and stowage plan for Ro-Ro ship. The tool will provide real-time information of identification and tracking of goods to all stakeholders in Ro-Ro terminal logistic operation keeping transparency of the process. Murgoitio et al. (2016) also discussed about AUTOPORT project to automate the roro terminal, using vehicle sensors and automation like Automated Guided Vehicle (AGV) can be controlled from terminal centre room to load and unload the trailer on Ro-Ro ship effectively according to cargo stowage plan.

In a similar way Park et al. (2022) proposed to automate the Ro-Ro terminal operations (loading/unloading process) using AGV technology. Although Park et al. (2022) used Arena 14.0 simulation model to test and analyse the loading/unloading operation. In the study, experiment conducted that showed the results in identifying the failures in advance and found

out that vehicles nearest to the ship should be prioritised and loaded first that will optimize the terminal performance. Park et al. (2022) also states that using AGV in the future would solve the problem of labour shortages and reduce human errors. Since AGVs are mostly used in container terminals because of standard size of container. Park et al. (2022) pointed out the limitations for Ro-Ro terminal, that use of AGVs to load the vehicle differs as there is no standard size of vehicles and varies with the different size of Ro-Ro ship.

Henessey et al. (2020) described in the study that adopting Blockchain and Internet of Things (IoT) would improve load planning of Ro-Ro ships. Henessey et al. (2020) states that implementing digitalisation technologies in the port will result in making a “smart port” and become fully automated port. For improving the load planning, Henessey et al. (2020) developed a simulation model and used C++ language programming to simulate the load planning process. Additionally, Henessey et al. (2020), founded that using sensors on vehicle at the check in gate, the weight of vehicles could be known. Once the cargo weight is known, the cargo load planning can be made in real-time using load planning management tool.

Since the yard time is dependent on area available in a yard, then area capacity for parking of vehicles in yard has direct impact in calculating the terminal performance (Morales-Fusco and Sauri 2009). To calculate the yard time, Morales-Fusco and Sauri (2009) through their research in Ro-Ro terminal suggested that distance between ramp and the parking of vehicles/cargo should be known and using the mathematical calculation, distance can be reduced to improve yard time. In terms of storage, Chen et al. (2021) had investigated using mathematical model for the Storage Location Assignment Problem (SLAP) for arrival of cars at the yard. Chen et al. (2021) formulated a car layout loading sequences in an automotive Ro-Ro terminal. This design will contribute to enhancing loading efficiency and better utilization of yard capacity. The Chen et al. (2021) further showed that experiment done specifically for the cars loading/unloading process and excluded other types of cargo (trailers/trucks).

Zhou et al. (2021) proposed a modern tool as Decision Support System (DSS) for port resilience using DT – based analysis and simulation – optimization algorithm to predict port performance. The DT model through numerical experiment based on real scenario of a container terminal identifies the disruption in the port events and resolves the uncertainty, thus recommending the port operators that the port is resilient (Zhou et al., 2021). While coordination between port operation and vessel scheduling has been improved by utilizing the DT model in predicting of vessel arrival time and proposed model would save carbon emissions and achieve decarbonization goal in the future (Eom et al., 2023).

Wijaya and Nakamura (2024) proposed a technique to process AIS data and utilizing the data to construct the ships trajectory into identifying whether ship is at an anchorage or moored. Additionally, fain-grained technique used in the study is a mix of relevant information from AIS generated trajectories showing ships state such as stopped (berthing or anchorage) or underway in the port vicinity, which give results in estimating the vessel turnaround time to construct the port performance indicator (Wijaya and Nakamura, 2024).

2.5 Vessel Turnaround Time

A vessel turnaround time is the total time a ship stays in the port from arriving till departure (Gurudev and Shetty, 2021). Ships berthing/unberthing time from port, cargo operation time (loading/unloading), bunkering, customs, inspection, and waiting time at anchorage comes under vessel turnaround time (Gurudev and Shetty, 2021). However, in contrary Ducruet et al. (2014) stated that turnaround time meaning as per official port statistics is not evident whether total time spent from ship arrival till departure in the port or just the time spent at the berth terminal.

According to Morales-Fusco and Sauri (2009), turnaround time of ship must be reduced to achieve high performance in a competitive shipping industry and important measure for Ro-Ro terminal operations. Furthermore Morales-Fusco and Sauri (2009), in the study highlighted that the total time of ship depends on the size, cargo capacity and even design of the ship. Considering the Ro-Ro ship the vessel turnaround time would vary a lot because of the ship design which includes number of platforms, number of ramp and its locations (side, forward or stern) and type/quantity of cargo (truck, trailers or cars) and its operation (Morales-Fusco and Sauri, 2009).

Gurudev and Shetty, (2021) critically identifies factors that affect the vessel turnaround time. In the study the author identified categories and the subsequent factors faced by the vessel in a port. Some of the major factors highlighted were bunkering, weather/tide problems, unavailability of berth, documentation, port holiday, machinery failure and its maintenance, cargo operation, cargo delay and any other factor.

Jia et al. (2022) identified that using dual cycling operations in Ro-Ro terminal would reduce turnaround time of vessels. In the study, Jia et al. (2022) presented a mathematical formula for Ro-Ro dual cycle using integer programming problem will improve loading/unloading operation and effectively result in shorter turnaround time for vessels. The vessel traffic scheduling optimization problem presented in Jia et al. (2023), determine the berth allocation, scheduling and waiting time of Ro-Ro passenger ship in the restricted harbour basin in a busy Ro-Ro passenger terminal. Jia et al. (2023) solved the scheduling optimization problem using a multi-objective mathematical model of an adaptive ant colony optimization algorithm (AACO). This model resulted in reducing total scheduling and waiting time of the ship. Jia et al. (2023), even suggested to use real-time data for vessel traffic scheduling by incorporating a vessel management platform for arrival of ships in the port.

3 Methodology

The chapter presents introduction of methodology used for the thesis. First, a literature review (Hammond and Wellington, 2020) was conducted and then derived from literature, a theoretical framework was constructed in guiding the empirical findings and formulated the interview questions. After that introduced a single case study (Yin, 2014), that included the interviews and finally concluded with describing the data analysis process.

The methodology comprises of a deductive research approach, that has been applied to develop the Theoretical Framework. Deductive research begins with an established theoretical knowledge from existing literature and then used to examine how these concepts work in the real situations (Spens and Kovács, 2006). This approach employed to explore operational efficiency and optimization initiatives of Ro-Ro terminal operation.

For the thesis, a qualitative research method was employed to understand in depth knowledge of the operational process and stakeholder's views. Using qualitative research helps in developing the context of the study by understanding the persons or an entity nature, getting insights from their views, values, response, experiences and behaviours (Ograjenšek, 2016). Generally, the qualitative research is often regarded as non-numerical data used for the research. According to Tisdell (2025), researcher conducts interviews, observations, and utilize documents as a primary method for the data collection and analysing them in qualitative research. This is usually done to investigate, understand, discover the new case and analysing with existing theoretical knowledge. Furthermore, the thesis includes a single case study to provide an overview and used as to collect the empirical data from semi-structured interviews from stakeholders involved in operation at Ro-Ro terminal.

3.1 Literature Review

The thesis study commences with the systematic literature review (Hammond and Wellington, 2020) process, to find relevant theoretical knowledge from scholarly papers. To accomplish this a qualitative approach had been employed to find the valid articles related to keywords from the thesis title and research question. A systematic literature review is used to find the relevant literature from a list of databases systematically and then organise the findings and synthesize them into a theoretical framework, regarded as reliable source for the reviewers (Hammond and Wellington, 2020).

The initial search started with finding the relevant keywords and are as follows: -

1. Ro-Ro Terminal
2. Ships Estimated Time of Arrival (ETA)
3. Port Operation
4. Port Efficiency
5. Port Digital Twin
6. Automatic Identification System (AIS)
7. Vesel's Turnaround Time

After the keywords were found and considered relevant to begin the search, search databases were used such as Scopus, google scholar, Chalmers library (EBSCO), and google. Initially

Scopus database search engine used as it includes wide range of academic papers. Since the initial search showed non-relevant papers in enormous number, inclusion/exclusion criteria were formed to filter the search as shown in Table 2.

Table 2: Inclusion/Exclusion Criteria

Inclusion	Exclusion
English language papers	Non-English or Other language papers
Peer reviewed/Academic journals	Grey Literature, Blogs
Time Frame (2000-2025)	Papers older than year 2000
Title and Abstract matched the purpose of this study	Non-relevant to keywords

Then the keywords were used as input in the Scopus search query which resulted in more than 10,000 papers. The published literature from year 2000-2025 were included for literature review. Then it was limited by using the sort by as “date (newest)” to find the recent published papers and then reduced based on the inclusion criteria. This was decided as new research were more relevant for the study to match the results from outcome of the interview and statistical data. After reading through headlines and abstract, final papers were selected for the literature review as shown in Table 3.

Table 3: Initial keywords search

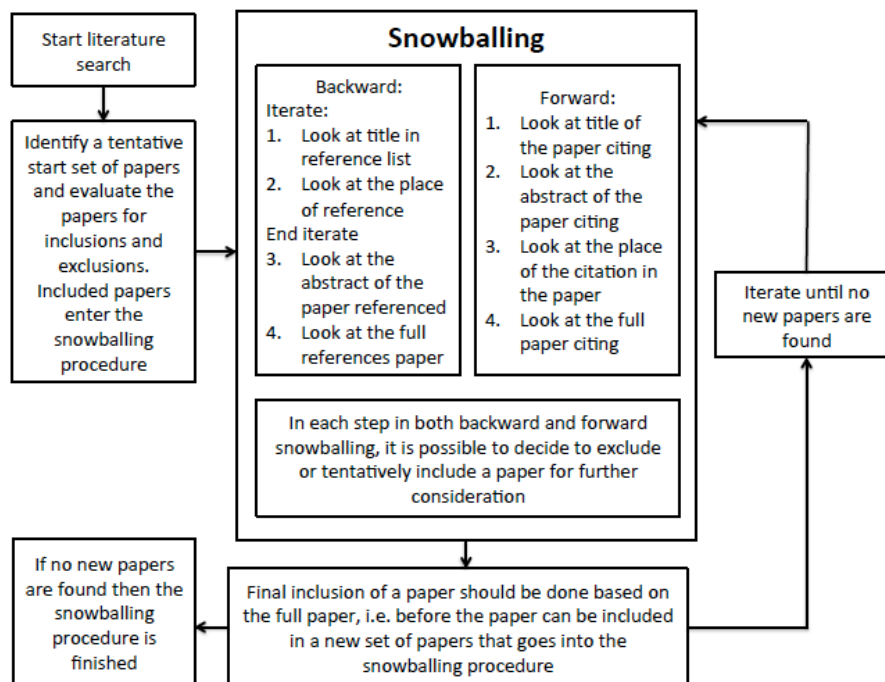
Keywords Search	Initial results	Headlines or Abstract Read	Papers selected
(Maritime AND port operation)	37753	86	2
(Maritime AND port AND digital twin)	30	12	5
((RORO OR Roll-on Roll-off) AND terminal)	42	22	5
Total	37825	120	10

In addition, Google scholar was also used as a search engine for finding more peer reviewed papers related to topics using relevant key words. Likewise in Scopus, similar approach was employed using inclusion/exclusion criteria to filter the relevant publish papers. Although, result showed more than 10000 numbers of papers for each keyword, the results shown on the first page were reviewed. However, the filter options were limited to select only for year range, the papers with highest citation included in the thesis research. These relevant papers are then

checked through Chalmers library (EBSCO) for the reliability (peer-reviewed/academic journal).

All the papers found were put in the respective folders such as AIS, DT, port operations, Ro-Ro ship, Ro-Ro terminal, and maritime port optimization. Although, primary search method based on database search, snowballing technique method was applied to find additional relevant papers. Once the relevant papers were selected, then these papers were thoroughly reviewed and included in the thesis. A snowballing technique was used to find the relevant papers which include backward, and forward snowballing as described by Wohlin (2014). The first step of backward snowballing process started with screening the title and the publication year in the reference list related to the topic (Wohlin, 2014). After finding the papers on search database, it was decided to read only abstract before including the entire paper for literature review. Then only the relevant papers were included in the thesis related to the topic. Additionally, conducted forward snowballing used for finding the relevant research papers which had cited that paper most recently. (Wohlin, 2014). The snowballing technique or procedure explained by (Wohlin, 2014, p. 4) were shown in Figure 3.

Figure 3: Snowballing Technique (Wohlin, 2014, p. 4)



Finally, a total of 47 papers were included by primary search and secondary snowballing method, out of which 38 were peer-reviewed/academic journals and other nine papers were also included which were conference reviewed paper or a book. However, the exact number of papers at each step from snowballing method was not systematically recorded. Therefore, these 47 papers were used to formulate the theoretical framework which are relevant to the thesis study.

3.2 Case Study

According to Yin (2014), a case study is considered most useful research approach in investigating a given industry of a particular area and provide a holistic view in collecting data. Gothenburg Ro-Ro terminal is the biggest Ro-Ro / Rail terminal in entire Scandinavia's region. It is owned by two shipping companies that are Det Forenede Dampskibs-Selskab (DFDS) and Compagnie Luxembourgeoise de Navigation (CLdN). The terminal handles more than six million tons of goods in a year. The goods are in form of rolling cargo such as trailers, vehicles, containers and cargo on cassettes which makes the terminal an important part of the supply chain and logistics. There combi terminal is strategically located close to the important central European highways and is also directly connected to several railway.

Terminal handles the transshipment of wagon loads, and intermodal traffic take place for further transport on vessels and trucks to destinations, the UK, turkey and on the continent. The terminals are open daily and run by professional employees managing the Ro-Ro and rail efficiently. The terminal can tailor highly efficient handling of all kinds of goods, from steel and paper to sand and passenger cars. Which defines the terminal most efficient and sustainable among all stakeholders.

The Gothenburg Ro-Ro terminal consists of six berths, and one is under construction. That handle around 1,500 units end 220 intermodal transports days. Every year, we roll on roll off 320,000 units, (all handling takes place 24/7 year-around). 1 million tons of paper, and 100,000 newly produced passenger cars. In total, we handle over 6 million tons of goods each year. Terminal also acquired a unique electric forklift with a 16-ton capacity. Which discharge the same amount of carbon dioxide under 21 days as diesel forklift does under a normal day of operation. This investment has resulted in reducing the carbon dioxide emissions to a minimum. The terminal is successfully run by 400 dedicated employees all of whom are specialists and highly involved in efforts to create a better, safer and more sustainable terminal.

The Gothenburg Ro-Ro terminal has a fixed schedule for DFDS vessels that arrive from ports such as Immingham, Brevik, Ghent, and Zeebrugge. The vessel sailing schedule for each week is same and the information is available on DFDS website. When there is change in the vessel arrival/departure schedule, a new amendment in the vessel schedule would be shared on their website. An example of vessel arrival/departure time schedule of DFDS vessel in Gothenburg Ro-Ro terminal from the Immingham route is shown in Table 4. From the interview and terminal visit it was found that the vessel schedule details are written on a white board and the assigned vehicles to be handled for discharge or loading cargo by stevedores are displayed on a digital screen for each of the vessel.

Table 4: The vessel Arrival/Departure time schedule in Gothenburg Ro-Ro terminal from Immingham (DFDS,2025)

Vessel time schedule in Gothenburg Ro-Ro terminal				
Vessel	Arrival	Day	Departure	Day
A	21:00	Sunday	19:00	Monday
B	09:00	Tuesday	19:00	Tuesday
C	09:00	Wednesday	22:00	Wednesday
A	09:00	Thursday	17:00	Thursday
B	09:00	Friday	20:00	Friday
C	11:00	Saturday	19:00	Saturday

3.3 Data Collection - Interviews

According to Yin (2014), interviews are conducted as a part of the case study. Interviews were conducted for empirical data collection of the stakeholders involved in the operations of the Gothenburg Ro-Ro terminal. Interviews were regarded as the conversations between the researchers and the interviewee (respondent), can be in a form of structured, semi-structured and unstructured (in-depth) interviews (Yin, 2014).

According to Taylor et al. (2016) an interviews guide is used by the researcher to give information about the researcher, knowledge about the research and what type of interviews will be used. Additionally, the interviews guide ensures that the interviewer would start the open-ended conversation with the interviewee and then take consent to record and use of the interviews data.

In the beginning, the author has formulated the interviews guide (introduction part), (see Appendix A). Tisdell (2025) described that all questions are flexible, open-ended and majorly relevant empirical data collected from all the respondents as part of the case study. Then the author had formulated semi-structured questions for each of the designated interviewee. (Tisdell, 2025) stated the semi structured interviews as mix of structured and unstructured interviews questions. So, the questions are formulated according to the findings from the theoretical framework, and the author ensure that these questions are not from own assumptions rather truly align with the deductive research approach. All the questions which were written in the word file and then discussed with the examiner and supervisor to include/exclude as per the relevancy for the thesis. This was done as author is new to this type of research method and asked for the guidance from the supervisor to keep the thesis more reliable and valid along the title and research question.

Once the questions were selected to be used for conducting the interviews then it is structured properly (see Appendix B) and then sent to the examiner and supervisor, to check again and get the feedback. The questions were then sent to the IT manager of Gothenburg Ro-Ro terminal, to check whether these questions were within their regulations and if not then changes would be made. Once the author got feedback from the IT manager, it was decided not to ask

that question during the interviews. Also, the IT manager helped in finding the right stakeholder's part of terminal operations and they could answer these questions as shown in Table 5. All the interactions between the author and the IT manager were done through mailing process which include the date, time, and venue for scheduling the interviews, or called as pre-interviews preparations according to (Greenfield and Greener, 2016). Then meeting was scheduled with the respondent and interviews was conducted as offline (person-to-person in Gothenburg Ro-Ro terminal) and online (Microsoft Team meeting used) as per the time availability of the interviewees.

Table 5: List of Interview Respondents

Respondent	Designation	Area of Expertise	Date of Interview
1	Digital Development Manager	IT operations	16-04-2025
2	Bridge Manager	Cargo and vessel coordinator	29-04-2025
3	Ship's Cargo Officer	In charge of Cargo loading and unloading on Ro-Ro ship	06-05-2025

According to Greenfield and Greener (2016), all the interviews were recorded and described as gaining access or consent to record the interviews information in a digital format or taking note manually. The author made sure to the interviewee, that recorded interviews data will be used only for the purpose of thesis and store them in own personal computer. Also, the author asked the interviewee whether they need a copy of the data or transcript as an ethical measure to ensure that data will be kept confidential, and the respondents will be kept anonymous. Furthermore, author recorded the interview in a digital format using Microsoft Teams meeting and used the option of "recording and transcribe" in English language.

Once all the interviews were conducted, the author downloaded the transcript and checked with the audio-video recording whether the transcription matches the same. It was found that the transcribed data was not matching completely as per the conversations. Then the author used

Microsoft 365 software, in this a new Microsoft word file opened. Process of transcribing through Microsoft word are as follows:

1. Open new Microsoft word document from Microsoft 365 software in the computer.
2. Then click on “Home”.
3. Click on “Dictate” -> “Transcribe”.
4. Select language for transcript as “English”.
5. Upload the audio-video from the computer, this will be uploaded to OneDrive account.
6. Then click on “Transcribe” (option chosen “labels with speakers”), which will start transcribing in the blank page.
7. Save the file.

Then the author checked the transcript file and matched with the recording from the interview’s conversations. It was found that this transcript exactly matches with the recorded conversation and can be used for analysing the interviews to write the results.

3.4 Data Analysis

According to Yin (2014), the data analysis is done to examine and test the findings from evidence for a new hypotheses or propositions. The thesis employed pattern matching techniques to compare the empirical findings (primary data) with the theoretically expected patterns and trends identified in the literature (Yin, 2014). The literature included in the Literature review was analysed for “coordinated approach for Ro-Ro port operation” and “digital technologies in Ro-Ro port operation” _with manifest content analysis (Boyatzis, 1998). The results of the Literature review were used as a guide to data collection from interview questions and as units of analysis (i.e., challenges in planning of cargo operations at the Ro-Ro terminal (Talley, 2006), planning of cargo operation at the Ro-Ro terminal (Iannone et al., 2016; Sauri et al., 2012), vessel scheduling in Ro-Ro terminal (Veenstra and Harmelink, 2021), digital technologies in Ro-Ro port operation (Eom et al., 2023; M’hand et al., 2019; Murgoitio et al., 2016; Neugebauer et al., 2024; Zhou et al., 2024)) in this study. Manifest content was used in the analysis using thematic analysis (Boyatzis, 1998) of the transcribed tape-recorded interviews by coding the responses. This involved assessing whether the interviewed data from terminal managers and the ship officer aligned with or differ from established patterns and trends. While the primary data source was interviews, triangulation (Hammond and Wellington, 2020) was employed by cross-referencing findings with the existing literature review.

4 Results and Analysis

This chapter includes results from the interviews and themes from the literature review presented in chapter 2. The interviews are analysed aligning with the literature review to describe the port operation and vessel scheduling in a Ro-Ro terminal.

4.1 Vessel Scheduling in Ro-Ro terminal

Interviews Result:

The respondent 2 described that the details of ships ETA receive 24 hours before arriving at the port. The respondent further mentioned that all the Ro-Ro ship has a fixed schedule and mostly all the ship arrives on time in the port. While respondent 3 mentioned that the details of ETA from the ships is send via email to the arriving port in advance. In addition, respondent 3 mentioned that sending ETA depends on port and their rules. Furthermore, added that they have a fixed schedule *“the ETA is always the same”*, so the ship arrives the same time or if there is any delay they adjust the speed to reach on time. Even in that situation they provide a new ETA as soon as they depart from the departing port. Similarly respondent 1 highlighted they have a system in the terminal where the ships schedule can be checked regularly.

Respondent 1 and 2 mentioned that to track ships they use real time data. While respondent 2 mentioned the online web portal *“we use marine traffic”*. Further respondent described that the terminal has a fixed berth for each ship arriving at the port. However, the respondent 3 mentioned that the ship’s Captain *“always sends an email right after departure that we will be arriving on time or maybe not on time.”* To check the ships ETA, respondent 2 mentioned that the planning department of Gothenburg Ro-Ro terminal always check when the ship departed from last port like Immingham port of United Kingdom. In addition, operation manager even calls the traffic department in the morning to follow-up if there is any change in the vessel schedule.

All the three respondents showed a consistent response that the ship is on fixed schedule, and the ETA is always the same for each vessel. While differ in their department role as respondent 1 ensures the system is showing correct ETA, respondent 2 ensures by following up of the vessel ETA and respondent 3 more focussed on fixed departure time to send ETA correctly. The terminal does not directly use the AIS data to track the ships movement but use an online web portal like Marine Traffic. Respondent 1 and 2 mentioned that they follow the ships tracking which aligns with the literature, suggested that terminal operators and stakeholders can establish an efficient decision making to improve the terminal operations through accurate ETA predictions.

The respondent 2 described that they keep a track of operation time which is an important factor for vessel turnaround time. In addition, the respondent 2 mentioned that *“it's very important for us to record time of the ship arrival and to finish the operation before the vessel is supposed to be departed. So, we're always tracking if there's any deviations.”* While respondent 1 mentioned that vessel turnaround time is one of their Key performance Indicator (KPI). However, they record the turnaround time manually but put in a digital form. Highlighting that they don’t have a system which automatically records the turnaround time digitally, but they

have a system in the terminal which records when the last cargo has been loaded on ship. However, respondent 3 mentioned that they are not responsible for recording the turnaround time and they follow as per the fixed vessel schedule.

Furthermore, the respondent 3 mentioned that ships take just 15 minutes to depart from the terminal area once the ramp is closed. Even while berthing the ship does not require tug as Ro-Ro ship is self-manoeuvred and all the captains holds the pilot license. Only when there is rough weather then only tugs assist the ship in berthing/unberthing. While all the three respondents showed a consistent response that departure is faster than berthing process and suggested to use past data to predict the pattern of ship arrival time.

Literature Review Results:

The literature highlights the use AIS data as a means for communicating the ship to shore and the ship's location can be tracked from websites such as Marine traffic and vessel finder. The AIS system provides static data filled by duty officer and dynamic data recorded automatically at an interval. As AIS data should always be in operation for real time tracking of the vessel, accuracy of vessel ETA can be obtained. The literature also highlights that the vessel turnaround time was affected by major factors like bunkering, berth allocation, cargo delay in the terminal and cargo operation. Additionally, it also varies on the size of the vessel and number of platforms for cargo operation. The published literature states that in a port operation, ETA of ship information provided by shipping companies is essential to plan vessel scheduling in advance. The literature emphasizes that using of real time data like AIS and ETA prediction for vessel traffic scheduling by including the management platform in the terminal would reduce the vessel turnaround time and improve the terminal efficiency. Overall, literature suggests that the terminal operations can be optimized through accurate ETA prediction and help in decision making for efficient terminal operations.

4.2 Planning of Cargo operations at the Ro-Ro terminal

Interviews Result:

Respondent 2 described the cargo planning in the Gothenburg Ro-Ro terminal process, the terminal gets the information of stowage plan, approximately 24 hours before the vessel arrival at the port. Furthermore, respondent described that the resource and planning department begins planning by using the planning tool, where they update the discharge and loading cargo information. However, this information is different for different vessel type and shared at the same time every day. In addition, respondent 1 mentioned that it depends on different criteria like the type of cargo for example hazardous or sensitive cargo. Although, respondent 2 mentioned an example for cargo information as *“Received the booking information about the 10:00 - 11:00. but it's usually the same every day.”*

Furthermore, respondent 2 mentioned that Dispatcher plans for cargo loading eleven hours before the vessel arrives. And the shift manager looks for the loading and discharging of cargo for that vessel. Once the discharge plan is available to shift manager, they know how to discharge the cargo *“As soon as we arrive, they just discharge the whole ship”* and plan for the loading of the cargo as per the loading plan. Similarly respondent 3 (ship's cargo officer)

described that once the ship arrives at the port, whole cargo is discharged from the ship by stevedores as per discharge plan. Furthermore, the dispatcher in the terminal shares the loading plan with the cargo officer. Once the cargo officer checks the loading plan in the Loadmaster program onboard for ships stability and accepted, then the loading begins on the Ro-Ro ship. In addition, respondent 1 states that loading officer prefer the load plan while considering weight distribution.

The communication between the dispatchers and the shipping line are coordinated via email, skype, phone calls, teams or chats, mentioned by respondent 1 and 3. Since the communication is established between the terminal managers and the shipping line and not between the terminal and the customers. This is because the terminal is owned by the shipping line and so they just act as bridge for cargo operation for the Gothenburg Ro-Ro ship. All the respondents were consistent in their response for the cargo operation process and highlighted proper coordination, and communication ensures for smooth terminal operation.

4.2.1 Cargo Arrival/departure process in Ro-Ro terminal

Respondent 1 described cargo operation begins with the cargo (example given for trailer to be loaded), booking done by the customer once the voyage schedule of vessel is known to them. Furthermore, the terminal manager gets the booking information of the unit which will be loaded onto the vessel. While the respondent 2 added and described about the terminal system which is used for vessel operation and yard operation.

In addition, respondent 1 describes further that the cargo arrives to the gate terminal. After that the gate allocate the unit to the general terminal area close to the birth. Respondent 2 further mentioned that systems shows where the unit is in the yard and ensures that driver should take the trailer at the designated storage area. *“there's an automated action in our terminal system.”* shows when the cargo arrives at the terminal and it becomes active in the system.

Furthermore, the respondent 1 described that the cargo unit then loaded directly on the Ro-Ro ship rather than dropped off at the yard. Similarly respondent 2 also highlighted *“And when the cargo leaves the terminal or loaded on ship, it shows completed.”* All this process were completed by the system in place in the terminal and they are quite flexible.

Both the respondent 1 and 2 showed consistent result and mentioned that the cargo arrival at the terminal is smoothly done with the terminal system in place, the terminal is much efficient in handling of incoming cargo.

4.2.2 Cargo operation time

The respondent 2 described that the cargo operation time depends on vessel, cargo type, staff and deadline. Furthermore, explained the process of cargo operation that there is a deadline for incoming cargo (loading cargo) at the terminal and that is one hour before the departure of the vessel. However, respondent 1 highlighted the similar process of cargo operation and added that the cargo which arrives one hour before departure will only be loaded and if there is delay for any reasons then the cargo will be loaded on to the next vessel.

While respondent 3 emphasized on the vessel fixed schedule in the terminal and cargo operation should complete before the vessel departure time. All the respondent showed consistent response as all DFDS ship arrival/departure time is on a fixed schedule for each week in Gothenburg Ro-Ro terminal. Since all the DFDS ship arrive in daytime and they stay in the terminal for nine to twelve hours. In the night, the stay of the vessel time is much shorter than the daytime which is between six to seven hours.

Respondent 2 explained that during the daytime customers must obey the deadlines to send the cargo in terminal and loading can be completed. While in the night, operation time is little bit shorter as the terminal must do a lot of work to meet the deadlines. The operation time varies between day and night. In addition to this, respondent 1 mentioned that they already know what type of cargo should be loaded on ship because its already arrived at the terminal in the daytime. Furthermore, respondent stated that terminal staff prepare the machines and chassis for the night shift in advance. In addition, respondent 2 states that *“We work a lot different during the night calls compared to the day calls.”*

All the respondents emphasized that cargo operation time is a crucial factor which impacts the terminal efficiency. While 1 and 2 respondents differ as highlighted day versus night operations and respondent 3 stressed on fixed departure time of the ship.

4.2.3 Cargo Dwell Time

Respondent 1 and 2 have been described that discharged trailers are stored mostly in the yard before the customer picks up from the terminal. While cargoes such as cars and trucks were often directly loaded or discharged during the time ship was berthed in the terminal. Furthermore, respondent 2 mentioned that the terminal has a fixed area for both import and export cars. However, for the trailers it depends on how many units are on the terminal and what's the situation of import and export standing in that area.

Respondent 2 highlighted that cargo in the yard also depends on day-to-day basis as some days there are more cargo and on other days terminal has less cargo. Similarly, respondent 1 mentioned that cargo in the yard varies with size of cargo and area it takes for storage. Furthermore, highlighted that they track the movement of cargo location in the yard on their terminal system, still lacks the predicting of cargo congestion due to delay in vessel berthing or cargo arrival from customers.

In addition, respondent 2 mentioned that *“usually trailers and other rolling units, not cars or trucks or machines take the longest time to discharge or load.”* While respondent 1 and 3 given a similar response that the trucks and cars discharged immediately as the ship berths. But the trailers and cargo on cassettes take longer time to load or discharge. All the three respondents showed a consistent response related to load/discharge time for different types of cargo.

For the cargo, which is stored at the yard, it is important to track the time of the cargo staying there before its being loaded on ship or picked up by the cargo customers. Respondent 1 mentioned that cargo dwell time is monitored and recorded in digital form using the terminal system as cargo arrival and departure timestamp from terminal used. *“Yes, we do have a power BI dashboard for that. And we also use it. Yeah, it's from our terminal system. so, mostly it is in a digital form.”* Similarly respondent 1 agreed with the respondent 2 using of digital form

for tracking the dwell time of the cargo in the terminal. Furthermore, both the respondent emphasized to use the data to optimize the terminal efficiency, while respondent 1 mentioned that it requires more research and adoption of latest technology.

Literature Review Results:

The published literature highlights the cargo operations in terminal beginning from the vessel berthing. Then unloading process starts according to unloading plan, while the cargo unloaded either transferred to the yard location or send directly to the customer. After that cargo loading process followed as per the stowage plan. All the cargo loading and unloading operation is carried by stevedores. Literature underlines that Ro-Ro terminal function as a link between sea and land and important for fast logistic operation. Additionally, literature highlights that semitrailers are loaded first and unloaded at the last from the vessel. While the cargoes such as trucks, cars, buses and passenger vehicles are unloaded first and loaded last. Literature emphasized for standardized approaches for cargo handling (semi-trailers) using EPCIS standard to improve the logistic operation in a Ro-Ro terminal. Furthermore, proper track and trace using terminal system for cargo operation would enhance the terminal efficiency.

4.3 Challenges in planning of cargo operations at Ro-Ro terminal

Interviews Result:

Respondent 1 and 2 have mentioned that in the Gothenburg Ro-Ro terminal the cargo can arrive one hour before the ship's departure time. Problem arises when the cargo customers decide to send the cargo at the last minute which results in changing the loading plan and the terminal must manage accordingly. Similarly, Respondent 3 mentioned about the port operation challenges that last minute change in cargo loading plan compromise the stability of the ship. All the respondents agreed that change in cargo loading plan as one of the significant challenges in the port operation.

In addition, respondent 1 mentioned that when there is tight deadline for ships departure, predicting the actual arrival of cargo sent by customers at the terminal is still a challenge. Also, the respondent 3 mentioned that the ship has a fixed departure time. Furthermore, respondent described that operational pressure arises when the ship takes bunker and at the same time change in cargo loading plan.

However, respondent 2 described the operational challenge in relation to daytime arrival of cargo and expected to load immediately from the Gothenburg terminal on ship. *"If the cargo does not arrive on time to be picked up. It's a congestion on the terminal because if you have a lot of units standing on the terminal, it's harder for us to do both loading and discharge the vessel coming in. That's the big challenge."* Respondent 3 compared with the ports like Immingham where the cargo has already arrived on the terminal, which allows them to plan everything in advance. Respondents 1 and 2 agreed that cargo loading plan is more cumbersome in Gothenburg port terminal than Immingham port.

Respondent 2 also mentioned the challenges related to available resources as stevedores in the terminal. Furthermore, the respondent described that the unfixed staff that handles the cargo were very few and if there is delay in ships berthing then it became difficult for the terminal to

utilize the resource efficiently. Although, respondent 1 mentioned that there is system in place to organise staff for cargo operation when plan is known in advance. But lacks the flexibility in adapting in the system at last minute changes. Moreover, the staff is utilised from the fixed pool of staff. It affects the performance of the staff resulting in the port operation inefficiency. However, respondent 1 and 3 agreed that tackling the challenge related to resource is still not resolved when ship got delays.

All the responses highlight a consistency in findings that changes in load plan create a disruption in port operation at different levels. While they all have a different perspective highlighting the challenge according to their role. Therefore, respondent 1 emphasized on the resource constraint, respondent 2 focussed on outdated system integration in the terminal operation and respondent 3 pointed out the concerns of ships stability.

Literature Review Results:

The literature highlights challenges as uncertainty related to arrival of ship and bunkering causing delays in cargo operation. Similarly, delay in cargo arrival from the customers causing port congestion and interrupt the entire terminal cargo operation. Additionally, challenges as disturbances related to stevedoring process caused by longer stevedoring handling time leads to delay in cargo operation. Also, load plan gets challenging depending on the type of cargo. The literature also highlighted the measures to tackle the challenges such as using of AGV to solve the labour shortages and implementing simulation model for load planning. To resolve the challenges associated with planning in cargo operation requires coordination between different stakeholders and subsequently improve the terminal efficiency.

4.4 Digital technologies in Ro-Ro port operation

Interviews Result:

The respondent 1 has mentioned about the technologies which are been used as part of the port operation in the Ro-Ro terminal. In addition, respondent described that *“Almost all trade cars have labels on them with a bar code”*, which can be scanned but the terminal doesn't use in them in the terminal. Reason mentioned by respondent 2 as the terminal doesn't want any congestion or delays in the cargo operation.

Furthermore, the respondent 1 described that all the vehicles are equipped with either GPS tracker or RFID. The respondent additionally mentioned that *“but they are not so much used for arriving or departure, loading and discharging”*, reason given as they cannot afford to have stops in proximity of vessel area. While highlighting that it would require installing scanning equipment like OCR (optical character recognition) or place more people to scan manually near the berth area or ship ramps. Similarly respondent 1 and 2 showed consistent results that any congestion near the vessel area of cargo flow would disrupt the operation and reduce the terminal efficiency.

While respondent 1 mentioned that the terminal does not have any problems when it comes to track and trace by the cargo customer. The use of GPS tracker on the vehicles would give information to the logistics party about the movement of their cargo. Although the information is not shared from the terminal side rather shipping line is responsible to provide that.

Respondent also highlighted “*we don't share our information with 3rd party customers because they are not our customer.*” Similarly, respondent 2 agreed with the respondent 1 regarding sharing of cargo information. In addition, the respondent mentioned that the terminal will take the responsibility. From the time cargo arrive at the terminal gate and loaded on the Ro-Ro ship and when discharge from ship to exit the terminal gates. However, respondent 3 mentioned that real time information sharing would improve coordination and communication between the terminal and ship staff.

Respondent 1 showed interest and supported while emphasizing in installing the new equipment's. Further highlighted, “*can have track and trace of units by using the CCTV*” in the terminal makes terminal efficient, although this transformation and adoption would take years to be successful. However, all the respondents agreed that using real-time information of identification and tracking of goods will give transparency of the process to all stakeholders in Ro-Ro terminal logistic operation.

One of the common questions that was asked from all the interviewees was about views on using DT in optimizing the port efficiency. Respondent 1 was aware of the DT concept, while respondents 2 and 3 were explained by the author about the DT simulation model for optimizing the port efficiency.

Respondent 1 showed a very positive response on using the DT in enhancing the port efficiency. Further respondent mentioned that “*AI is a great tool. I think the problem is to get the AI into the system*”. Highlighting further on issue that to build the robust system would take a long time and this would require framework and upgrade gradually. Similarly, respondent 2 was also showed a positive response in utilizing the DT stating that this would improve the terminal operation. In addition, the respondent mentioned that “*through the data that's collected on the terminal, there is a lot to do to make it both better and smarter operation with the use of AI and machine learning.*” But showed some concerns regarding the factors influencing the implementation as highlighted that “*it's a dynamic operation here at the terminal*”. Respondent 3 also showed quite positive response that it's a great thing to implement, making operation more efficient.

All the respondent showed a consistent response. While respondent 1 and 2 who are working for the terminal operation are being more positive to be part of developing the DT simulation model for the port. While respondent 3 differ as their role is not related in the terminal improvement.

Literature Review Results:

Published literature highlighted digitalisation and adopting new technologies in the terminal operation. Additionally, literature underline that using technologies (Barcode, Magnetic card ID and QR code on the cargo or vehicles) to gather information from real-time data would reduce the checking time and increase flow in improving overall performance of the terminal. Since the DT concept is new in the shipping industry and just some ports successfully implemented in the port infrastructure like container terminal as showcased in published literature. The use of DT in remaining types of port is still in research planning phase. And all the ports are visioning to make them port more digitalise to predict uncertainty and enhance port efficiency. Literature emphasizes that collecting the real-time data from ships and terminal operation such as vessel arrival time in berth scheduling, cargo allocation in the yard, cargo

stowage planning, and integrating them to make schedule planning on DT platform would enhance the terminal efficiency. Literature also emphasized on coordination between different stakeholders utilizing the DT model by predicting of vessel arrival time and cargo arrival at the terminal would optimize the terminal operation.

5 Discussion

In this chapter of the thesis, discusses the findings from literature review and interview data. The discussion combines insights from the results, showcasing key themes and their implications. Each of the key themes from the results are being discussed in an elaborative approach and suggestions for the future implications. This chapter is divided in five sections, first four sections discuss the themes from result, and fifth section discusses the methodology used for the thesis.

5.1 Vessel scheduling in Ro-Ro terminal

In the port, vessel scheduling is a key aspect because cargo arrival and departure depend on that. If the cargo customer is unaware of the vessel schedule, then this will interrupt the logistics operation and can result in huge losses. From the terminal side, it's an important work to know exact time of ships arrival so that they plan the resource in an efficient way. Even the correct departure time will allow them to plan that how much time they must carry out the loading/unloading operation smoothly.

The findings from the results showed that the terminal receives the ships ETA 24 hours in advance which is described in the literature by Veenstra and Harmelink (2021), the first ETA is sent within 12-24 hour before actual arriving the port. After that they start planning the resource for port operation of that ship. Since the DFDS ship are on a fixed schedule, ships ETA is still shared with the terminal via email once the ship departed from the last port. Although the terminal manager tracks the ships movement on Marine Traffic, still ETA is needed as an official confirmation between ship and the terminal. this is done so that in the event of ship gets delayed then the terminal can know in advance of any change and make operational plans accordingly.

Another KPI is vessel turnaround time which is important factor considered when improving the port efficiency. While the terminal manager described that they record the turnaround time manually and record that in digital form, but they don't have any system like DT simulation model that can identify bottlenecks and suggest ways to improve the operation. Even turnaround time could be reduced when using dual cycling operation in Ro-Ro terminal Jia et al. (2022), but this could not be identified as DFDS ships was not accessible to justify the results.

From the interviewees, it was found that the ship or the terminal doesn't use real-time AIS data to track or predict the ships ETA as they are still relied on the fixed schedule. Although according to Emmens et al. (2021), which showed in their research that AIS data is useful in predicting the ship arrival pattern and help in adjusting the cargo logistics. Hence it is recommended to Gothenburg Ro-Ro terminal to use AIS data to optimize the port operation.

5.2 Planning of Cargo operation at the Ro-Ro terminal

As cargo operation is one of the key performance indicators for any terminal described by (Notteboom et al., 2021a), it's important to know how they are managing and what all process

are there in the port operation. It starts with the arrival of ship in the terminal. once the ship is berthed and ramp lowers down the stevedores unleash the cargo and starts discharging them. The cargo then picked up by the cargo customer once they exit the terminal gate. And if the customer doesn't pick the cargo, then it is being stored at the yard which led to dwell time.

For the cargo to be loaded, a stowage plan is shared with the dispatcher in the terminal from the ships loading officer. The cargo arrives at the terminal, and the timestamp is recorded for the entry in the terminal system. The terminal can look the booking information and can plan the cargo sequence for the Ro-Ro ship. Even at the terminal gate the sequence is known and whether the cargo would be loaded directly into the ship or need to be stored near the berth area which will then be loaded afterwards as per the sequence. This all planning is done before the loading process could start and coordinated between the dispatcher and ships loading officer.

The cargo operation by the terminal is an important factor which is evaluated to know that the port is efficient in handling the cargo and how well they are performing while competing with same type of terminal. The cargo operation time and dwell time are recorded by the terminal in digital form is not utilized to predict the problem of cargo delay and congestion. But with the use of artificial intelligence and machine learning, the terminal could improve the port efficiency by eliminating the problems and could utilize the full potential to improve further.

5.3 Challenges in planning of cargo operations at Ro-Ro terminal

One of the common key challenges highlighted by all the interviewees is that the cargo for loading can arrive at the terminal one hour before the ship's departure time. This creates a tight deadline for the terminal staff to manage and in the event of maximum cargo arrives at the same time, the terminal must deal with the congestion. From the results it was found that the coordination is between the shipping line and the cargo customer, this makes difficult for the terminal to handle this challenge. The congestion or last-minute change in the cargo loading plan also a concern for the ship loading officer to change in the loading plan. But this problem is solved immediately as the coordination between the ships loading officer and terminal dispatcher in efficient planning.

Another challenge faced by the terminal is the resources, which can impact the planning for loading/discharging operation. Also, highlighted that vessel delay can lead to finding the resource for handling the cargo. Here the resource is stevedores as they have a fixed schedule assigned for the ship and if the problem persists then the terminal has got the unfixed staff from different terminal. This led to cargo congestion as it creates more workload on the terminal staff to discharge the vessel and at the same time load the vessel. This could impact the overall efficiency of the port performance which was highlighted in the previous studies from literature.

All these challenges occur because of lack of coordination between the terminal and the cargo customer. As the terminal is owned by the two shipping lines and their work is limited to handling of cargo (loading/unloading) in the terminal. For an efficient terminal, it is important to assess and work for both the stakeholders – shipping line and the cargo customer, then only terminal can solve these problems as highlighted in the literature by (Talley, 2006) which

describes the vessel berthing on time and cargo ready for loading/discharging. Addressing the challenges of the terminal would improve the port efficiency.

5.4 Digital technologies in Ro-Ro port operation

As part of this question was to increase operational efficiency in the loading and discharging of cargo in the terminal, it was found from the interviews result that technologies would help in improving the terminal performance. The Gothenburg terminal is equipped with the terminal system which records the cargo import and export timestamps but still lacks in utilizing the technologies to improve the terminal for making it a smart port. Supported by Hennessey et al. (2020) states that implementing digitalisation technologies in the port will result in making a “smart port” and become fully automated port. As the terminal has no problem in installing sensors like OCR in the terminal which would be useful for transforming the terminal more digitalised. But the terminal had the limitations that the installation of new technological device would hinder in the smooth cargo operation and can cause congestion.

While the terminal was aware of the sensors which are equipped on trailers, cars and trucks like RFID, barcode and GPS tracker. These sensors are not used by the terminal hence no improvement in the terminal efficiency could be achieved. To improve the terminal efficiency the terminal must implement or develop new technological tools that is described by Murgoitio et al. (2016), that is Port Operation Management System (POMS) will provide real-time information of identification and tracking of goods to all stakeholders in Ro-Ro terminal logistic operation keeping transparency of the process.

DT is a new concept with the adoption of artificial intelligence and machine learning models. This concept would help in improving the maritime industry including all the operations like ships sailing, port infrastructure, and cargo supply chain. From the results of using DT simulation model in optimizing the terminal efficiency, would help the port in identifying the bottlenecks from the historical data of all the operations carried in the terminal. Once the problems are known in advance using the DT, it will help the terminal to predict and provide the necessary action to rectify and plan accordingly.

Not alone the DT would do all the work but also requires the human intervention who would take decision in improving the terminal efficiency. While DT would require historical data combine with real-time data and then analysing them, it would require lots of investment and installation of equipment. Hence the use of DT would largely require the coordination from all the stakeholders such as terminal operators, shipping lines, port authorities and cargo owners and will give real-time monitoring and tracking in the port operation (Eom et al., 2023).

5.5 Methodological Discussion

The method used in the thesis is a deductive research approach which includes literature review and qualitative approach (semi-structured interviews). The aim of the thesis report was to find the relevant knowledge through literature review about what studies were done historically in improving the terminal efficiency. Once the theoretical framework was formed, a single case study used that includes data collection from interviews. After the interview questions were

formulated, semi-structured interviews were conducted with the terminal operators ensuring reliability for the thesis approach to collect the current operational information. Then the themes derived from the literature review were analysed with the primary data collected from the interviews. This approach increases the validity of the study by comparing or contrasting and maintaining alignment between interview questions and literature review. Although, validity can be strengthened by including more respondents from different terminals.

6 Conclusion

The purpose of the thesis is to explore in establishing a coordinated approach for port operation and vessel traffic scheduling in Roll-on/Roll-off terminals to optimize the terminal efficiency. The aim was to identify the crucial challenges and current operational activities performed by the terminal in complex loading/unloading of cargo and vessel scheduling. Additionally, the thesis highlighted the coordination approach among different stakeholders involve in the terminal operations. The results of the thesis findings also highlighted the current digital tools and technologies used in the terminal operations of the flow of cargo.

RQ 1: How can the operational efficiency of a Ro-Ro terminal be optimized in complex loading and discharging operations?

Operational efficiency depends on key performance indicators like cargo operation time, turnaround time, stevedoring time and dwell time. To increase the terminal efficiency, it's important to understand the process of the cargo flow in the terminal. The research findings showed the terminal process from the data collected through interviewed stakeholders and highlights crucial challenges that affects the complex load and discharged terminal operations. The findings indicated challenges such as tight deadlines for cargo arrival, resource constraint and last-minute changes in loading plan affects the terminal efficiency. To combat these challenges, it is required to establish a coordinated approach through the stakeholders. Findings have been shown that implementing the digital technologies to predict the uncertainty of cargo flow in the terminal operation would optimize the terminal operational efficiency.

RQ 2: How can a Ro-Ro terminal optimize the operational efficiency through the adoption of digital technologies?

The research findings show that the terminal system is utilized to track and trace the cargo flow, entry from the terminal to ship and from ship to terminal exit in the Gothenburg Ro-Ro terminal. The cargo flow data gets recorded automatically. The research highlighted the ETA of the ship provided to the terminal staff through email and the planning for cargo operation were executed. The resource allocation and preparing the equipment for handling the cargo for fixed schedule are planned in advance. But for any uncertainty, the terminal needs to implement the adoption of DT technology. Additionally, it will require the historical data, real time data and then analysing the data using AI and machine learning.

While the findings from the interviews showed positive approach using the DT simulation model to predict the uncertainty. This will optimize the Ro-Ro terminal operational efficiency by adopting the digital technology that will streamline the cargo operation, resource allocation and vessel scheduling. In the shipping industry, digitalisation will enhance the cargo movement much faster and transparent to the customers in the terminal.

6.1 Managerial implications

It is essential for the Ro-Ro terminal to work among all the stakeholders which includes shipping lines, cargo/logistics owner, port authority and terminal operators. For that there should be a transparency between all the stakeholders and a proper coordination which will make the terminal efficient and would result in fast and efficient supply chain. To make the

terminal efficient, it starts with providing the real-time data of cargo and ship movement with all the stakeholders and to do so, the terminal needs to provide one stop system on their website. To be able to provide with the details of ship and cargo track and trace, the terminal needs to develop the system. To develop the terminal into a smart port, more investments is needed for digital infrastructure and development of DT simulation model.

6.2 Further research suggestions

Considering the small sample size of the interviews it is further recommended to conduct more interviews of the stakeholders involve in the terminal operations would strengthen the validity of the presented findings. Furthermore, research should also include collecting data from other Ro-Ro terminals to compare the operational functionality.

In the thesis research, the statistical data related to cargo operation time, turnaround time and dwell time could not be collected due to restrictions in access from the terminal. Therefore, it is further recommended to expand research in collecting the previous statistical data and real time data that will be used to develop DT simulation model. Additionally, the research should also include the data for different types of cargo movement in the terminal. Further suggestions could be research on investments required for the development of the digital tools and installing of technologies that will optimize the terminal efficiency.

- Bassan, S., Tel, B. N. T. A., & Metropolitan, A. (2007). Evaluating seaport operation and capacity analysis—preliminary methodology. *Maritime Policy & Management*, 34(1), 3–19. <https://doi.org/10.1080/03088830601102725>
- Bi, J., Cheng, H., Zhang, W., Bao, K., & Wang, P. (2024). Artificial Intelligence in Ship Trajectory Prediction. *Journal of Marine Science and Engineering 2024*, Vol. 12, Page 769, 12(5), 769. <https://doi.org/10.3390/JMSE12050769>
- Boyatzis, R. E. (1998). *Transforming qualitative information thematic analysis and code development*. Thousand Oaks, CA: Sage Publications.
- Bucak, U., Müjdat BAŞARAN, İ., & Esmer, S. (2020). Dimensions of the Port Performance: A Review of Literature. *Journal of ETA Maritime Science*, 8(4), 214–240. <https://doi.org/10.5505/jems.2020.76598>
- Chen, X., Li, F., Jia, B., Wu, J., Gao, Z., & Liu, R. (2021). Optimizing storage location assignment in an automotive Ro-Ro terminal. *Transportation Research Part B: Methodological*, 143, 249–281. <https://doi.org/10.1016/J.TRB.2020.10.009>
- Christodoulou, A., Raza, Z., & Woxenius, J. (2019). The integration of RoRo shipping in sustainable intermodal transport chains: The case of a North European RoRo service. *Sustainability (Switzerland)*, 11(8). <https://doi.org/10.3390/SU11082422>
- Development, U. N. C. on T. and. (2024). *Review of Maritime Transport 2024*.
- Dias, J. C. Q., Calado, J. M. F., & Mendonça, M. C. (2010). The role of European «ro-ro» port terminals in the automotive supply chain management. *Journal of Transport Geography*, 18(1), 116–124. <https://doi.org/10.1016/J.JTRANGEO.2008.10.009>
- Ducruet, C., Itoh, H., & Merk, O. (2014). *Time Efficiency at World Container Ports*. www.internationaltransportforum.org/jtrc/DiscussionPapers/jtrcpapers.html
- Durlik, I., Miller, T., Dorobczyński, L., Kozłowska, P., & Kostecki, T. (2023). Revolutionizing Marine Traffic Management: A Comprehensive Review of Machine Learning Applications in Complex Maritime Systems. *Applied Sciences 2023*, Vol. 13, Page 8099, 13(14), 8099. <https://doi.org/10.3390/APP13148099>
- Emmens, T., Amrit, C., Abdi, A., & Ghosh, M. (2021). The promises and perils of Automatic Identification System data. *Expert Systems with Applications*, 178, 114975. <https://doi.org/10.1016/J.ESWA.2021.114975>
- Eom, J. O., Yoon, J. H., Yeon, J. H., & Kim, S. W. (2023). Port Digital Twin Development for Decarbonization: A Case Study Using the Pusan Newport International Terminal. *Journal of Marine Science and Engineering*, 11(9). <https://doi.org/10.3390/JMSE11091777>
- Erena, O. T., Kalko, M. M., & Debele, S. A. (2021). Technical efficiency, technological progress and productivity growth of large and medium manufacturing industries in Ethiopia: A data envelopment analysis. *Cogent Economics and Finance*, 9(1). <https://doi.org/10.1080/23322039.2021.1997160>
- Evmides, N., Aslam, S., Ramez, T. T., Michaelides, M. P., & Herodotou, H. (2024). Enhancing Prediction Accuracy of Vessel Arrival Times Using Machine Learning. *Journal of Marine Science and Engineering*, 12(8). <https://doi.org/10.3390/JMSE12081362>

- Främling, K., Parmar, S., Hinkka, V., Tätilä, J., & Rodgers, D. (2013). Assessment of EPCIS standard for interoperable tracking in the supply chain. *Studies in Computational Intelligence*, 472, 119–134. https://doi.org/10.1007/978-3-642-35852-4_8
- Gharehgozli, A. H., Roy, D., & De Koster, R. (2016). Sea container terminals: New technologies and or models. *Maritime Economics and Logistics*, 18(2), 103–140. <https://doi.org/10.1057/MEL.2015.3>
- Greenfield, T., & Greener, S. (Eds.). (2016). *Research Methods for Postgraduates: Third Edition*. John Wiley & Sons, Ltd. <https://doi.org/10.1002/9781118763025>
- Gurudev, V., & Shetty, D. K. (2021). *Factors affecting the Vessel Turnaround time in a Seaport*. <https://www.researchgate.net/publication/350654572>
- Hammond, M., & Wellington, J. (2020). *Research Methods*. Routledge. <https://doi.org/10.4324/9780429058165>
- Harati-Mokhtari, A., Wall, A., Brooks, P., & Wang, J. (2007). Automatic Identification System (AIS): Data Reliability and Human Error Implications. *Journal of Navigation*, 60(3), 373–389. <https://doi.org/10.1017/S0373463307004298>
- Henesey, L. E., Lizneva, Y., Philipp, R., & Meyer, C. (2020). *Improved load planning of RoRo Vessels by adopting Blockchain and Internet-of-Things*. <https://doi.org/10.46354/i3m.2020.hms.009>
- Iannone, R., Miranda, S., Prisco, L., Riemma, S., & Sarno, D. (2016). Proposal for a flexible discrete event simulation model for assessing the daily operation decisions in a Ro-Ro terminal. *Simulation Modelling Practice and Theory*, 61, 28–46. <https://doi.org/10.1016/J.SIMPAT.2015.11.005>
- Iris, Ç., & Lam, J. S. L. (2019). A review of energy efficiency in ports: Operational strategies, technologies and energy management systems. *Renewable and Sustainable Energy Reviews*, 112, 170–182. <https://doi.org/10.1016/J.RSER.2019.04.069>
- Iyer, V. B. (2013). An Overview Automatic Identification System and Its Applications. *International Journal of Engineering Sciences & Research Technology*. https://www.academia.edu/5673591/An_Overview_Automatic_Identification_System_and_Its_Applications
- Jia, B., Tierney, K., Reinhardt, L. B., & Pahl, J. (2022). Optimal dual cycling operations in roll-on roll-off terminals. *Transportation Research Part E: Logistics and Transportation Review*, 159, 102646. <https://doi.org/10.1016/J.TRE.2022.102646>
- Jia, Q., Li, R., Li, J., Li, Z., & Liu, J. (2023). Vessel traffic scheduling optimization for passenger RoRo terminals with restricted harbor basin. *Ocean and Coastal Management*, 246. <https://doi.org/10.1016/J.OCECOAMAN.2023.106904>
- Kastner, M., Saporiti, N., Lange, A. K., & Rossi, T. (2024). Insights into How to Enhance Container Terminal Operations with Digital Twins. *Computers*, 13(6). <https://doi.org/10.3390/COMPUTERS13060138>
- Kishore, L., Pai, Y. P., Ghosh, B. K., & Pakkan, S. (2024). Maritime shipping ports performance: a systematic literature review. *Discover Sustainability*, 5(1). <https://doi.org/10.1007/S43621-024-00299-Y>

- Lee, E. S., Mokashi, A. J., Moon, S. Y., & Kim, G. S. (2019). The Maturity of Automatic Identification Systems (AIS) and Its Implications for Innovation. *Journal of Marine Science and Engineering* 2019, Vol. 7, Page 287, 7(9), 287. <https://doi.org/10.3390/JMSE7090287>
- Lun, Y. H. V, Lai, K.-H., & Cheng, T. C. E. (2010). Port Operations. *Shipping and Logistics Management*, 179–191. https://doi.org/10.1007/978-1-84882-997-8_13
- Maritime transport statistics - short sea shipping of goods - Statistics Explained - Eurostat*. (n.d.). Retrieved May 25, 2025, from https://ec.europa.eu/eurostat/statistics-explained/index.php?oldid=636756#EU_short_sea_shipping_decreased_by_5.4.25_in_2023_compared_with_2022
- M'hand, M. A., Boulmakoul, A., Badir, H., & Lbath, A. (2019). A scalable real-time tracking and monitoring architecture for logistics and transport in RoRo terminals. *Procedia Computer Science*, 151, 218–225. <https://doi.org/10.1016/J.PROCS.2019.04.032>
- Morales-Fusco, P., & Saurí, S. (2009). Performance indicators for roll-on-roll-off terminals. *Transportation Research Record*, 2100, 38–46. <https://doi.org/10.3141/2100-05>
- Morales-Fusco, P., Saurí, S., & Spuch, B. (2010a). Quality indicators and capacity calculation for RoRo terminals. *Transportation Planning and Technology*, 33(8), 695–717. <https://doi.org/10.1080/03081060.2010.527179>
- Morales-Fusco, P., Saurí, S., & Spuch, B. (2010b). *Transportation Planning and Technology Quality indicators and capacity calculation for RoRo terminals* Quality indicators and capacity calculation for RoRo terminals. <https://doi.org/10.1080/03081060.2010.527179>
- Murgoitio, J., Vázquez, F., Samaniego, R., Paz, E., Sachocos, M., Arejita, B., Urquiza, A., & Veiga, E. (2016). Spanish Initiative for Fully Automated Stowage on Roll-on/roll-off Operations. *Transportation Research Procedia*, 14, 173–182. <https://doi.org/10.1016/J.TRPRO.2016.05.053>
- Neugebauer, J., Heilig, L., & Voß, S. (2024). Digital Twins in the Context of Seaports and Terminal Facilities. *Flexible Services and Manufacturing Journal*. <https://doi.org/10.1007/S10696-023-09515-9>
- Notteboom, T., Pallis, A., & Rodrigue, J.-P. (2021a). Port Economics, Management and Policy. *Port Economics, Management and Policy*. <https://doi.org/10.4324/9780429318184>
- Notteboom, T., Pallis, A., & Rodrigue, J.-P. (2021b). Port Economics, Management and Policy. *Port Economics, Management and Policy*. <https://doi.org/10.4324/9780429318184>
- Ograjenšek, I. (2016). Theory and Practice of Qualitative Research. In *Research Methods for Postgraduates: Third Edition* (pp. 214–230). John Wiley & Sons, Ltd. <https://doi.org/10.1002/9781118763025.ch22>
- Park, K., Sim, S., & Bae, H. (2021). Vessel estimated time of arrival prediction system based on a path-finding algorithm. *Maritime Transport Research*, 2, 100012. <https://doi.org/10.1016/J.MARTRA.2021.100012>
- Park, S. H., Hwang, J., Yun, S., & Kim, S. (2022). Automatic Guided Vehicles Introduction Impacts to Roll-On/Roll-Off Terminals: Simulation and Cost Model Analysis. *Journal of Advanced Transportation*, 2022. <https://doi.org/10.1155/2022/6062840>

- Paulauskas, V., & Vytautas, D. (2020). Accuracy Evaluation of Ro-Ro and Ro-Pax Ships Arrival to the Ports. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, 14(2), 397–401. <https://doi.org/10.12716/1001.14.02.17>
- Ringsberg, H., & Lumsden, K. K. (2016). Logistic management of trailers based on the EPCIS standard: A cross-case analysis. *Research in Transportation Business and Management*, 19, 65–72. <https://doi.org/10.1016/J.RTBM.2016.04.002>
- Santos, T. A., Guedes Soares, C., & Botter, R. C. (2018). Characterizing the operation of a roll-on roll-off short sea shipping service. *Progress in Maritime Technology and Engineering - Proceedings of the 4th International Conference on Maritime Technology and Engineering, MARTECH 2018*, 77–86. <https://doi.org/10.1201/9780429505294-10/CHARACTERIZING-OPERATION-ROLL-ROLL-SHORT-SEA-SHIPPING-SERVICE-SANTOS-GUEDES-SOARES-BOTTER>
- Saurí, S., Morales-Fusco, P., Toledano, M., & Martín, E. (2012). Empirical analysis of resiliency of terminal operations for roll-on-roll-off vessels. *Transportation Research Record*, 2273, 96–105. <https://doi.org/10.3141/2273-12>
- Sepehri, A., Kirichek, A., van den Heuvel, M., & van Koningsveld, M. (2024). Smart, sustainable, and circular port maintenance: A comprehensive framework and multi-stakeholder approach. *Journal of Environmental Management*, 370. <https://doi.org/10.1016/J.JENVMAN.2024.122625>
- Shipping Routes & Schedules | DFDS (INT)*. (n.d.). Retrieved May 25, 2025, from <https://www.dfds.com/en/freight-ferries-and-logistics/routes-and-schedules>
- Spens, K. M., & Kovács, G. (2006). A content analysis of research approaches in logistics research. *International Journal of Physical Distribution & Logistics Management*, 36(5), 374–390. <https://doi.org/10.1108/09600030610676259>
- Svanberg, M., Santén, V., Hörteborn, A., Holm, H., & Finnsgård, C. (2019). AIS in maritime research. *Marine Policy*, 106, 103520. <https://doi.org/10.1016/J.MARPOL.2019.103520>
- Talley, W. K. (2006). Chapter 22 Port Performance: An Economics Perspective. *Research in Transportation Economics*, 17, 499–516. [https://doi.org/10.1016/S0739-8859\(06\)17022-5](https://doi.org/10.1016/S0739-8859(06)17022-5)
- Taylor, S. J. ., Bogdan, Robert., & DeVault, M. L. . (2016). *Introduction to qualitative research methods : a guidebook and resource*. 401.
- Tisdell, E. J. . (2025). *Qualitative Research: A Guide to Design and Implementation : A Guide to Design and Implementation*.
- Veenstra, A., & Harmelink, R. (2021). On the quality of ship arrival predictions. *Maritime Economics and Logistics*, 23(4), 655–673. <https://doi.org/10.1057/S41278-021-00187-6/FIGURES/10>
- Wijaya, W. M., & Nakamura, Y. (2024). Port performance indicators construction based on the AIS-generated trajectory segmentation and classification. *International Journal of Data Science and Analytics*, 1–20. <https://doi.org/10.1007/S41060-024-00614-W/TABLES/6>
- Wohlin, C. (2014). *Guidelines for Snowballing in Systematic Literature Studies and a Replication in Software Engineering*. <https://doi.org/10.1145/2601248.2601268>
- Yang, D., Wu, L., Wang, S., Jia, H., & Li, K. X. (2019). How big data enriches maritime research—a critical review of Automatic Identification System (AIS) data applications. *Transport Reviews*, 39(6), 755–773. <https://doi.org/10.1080/01441647.2019.1649315>

- Yang, Y., Liu, Y., Li, G., Zhang, Z., & Liu, Y. (2024). Harnessing the power of Machine learning for AIS Data-Driven maritime Research: A comprehensive review. *Transportation Research Part E: Logistics and Transportation Review*, 183, 103426. <https://doi.org/10.1016/j.tre.2024.103426>
- Yin, R. K. (2014). Case study research : design and methods / Robert K. Yin. *Applied Social Research Methods Series*, 18(2), 54–56. <https://doi.org/10.1097/00001610-199503000-00004>
- Zhou, C., Xu, J., Miller-Hooks, E., Zhou, W., Chen, C. H., Lee, L. H., Chew, E. P., & Li, H. (2021). Analytics with digital-twinning: A decision support system for maintaining a resilient port. *Decision Support Systems*, 143. <https://doi.org/10.1016/J.DSS.2021.113496>
- Zhou, F., Yu, K., Xie, W., Lyu, J., Zheng, Z., & Zhou, S. (2024). Digital Twin-Enabled Smart Maritime Logistics Management in the Context of Industry 5.0. *IEEE Access*, 12, 10920–10931. <https://doi.org/10.1109/ACCESS.2024.3354838>

Appendix:

A – Interview Guide, Validity Questions (Introduction Part)

My name is AVINASH GUPTA, I will be conducting an interview today for my master's thesis project, "Coordinated approach for port operation and vessel traffic scheduling in Roll-on Roll-off terminals: a case from Sweden". The interview will be held for about 30-40 minutes long.

The project focuses on optimizing the port efficiency in a Roll-on Roll-off terminal. That will reduce ship turnaround time by improving the loading and discharging operation of cargo using innovative technologies (DT). The participation is voluntary, and the interviewee can skip any question or stop interview anytime. The information from the interview will be confidential and will be used only for the purpose of the thesis project. Also, the interviewee's identity will be kept confidential.

I would like to record the conversation of the interview after getting your consent. (would you give the consent to record?)

The interview is structured in a semi-structured, which means some of the questions asked will be fixed or same and the remaining questions will be the follow-up to those questions in an elaborative way. Also, the question might deviate as per the answers given and this is to know your experiences and views, so there are no right or wrong answers. Since I have limited time to take the interview, I might interrupt in between the interview to move to the next question. This is because I need to cover as much question and to cover all the topics which are distributed in each question in the given time frame. I hope the interview would bring with great sharing of ideas and experiences. Thank you for your time and cooperation!

B – Interview Guide, Interview Questions

Port Manager

1. Can you describe work processes and responsibilities as port manager?
2. What are strategies used to optimize the terminal efficiency?
 - a. Land,
 - b. Sea,
 - c. hinterland?
3. How do you manage unpredictable events?
 - a. Vessel delay?
 - b. Cargo delay?
 - c. Weather uncertainty?
 - d. Emergency?
4. How many
 - a. berths are there in the Gothenburg Ro-Ro terminal?
 - b. Trailers etc handled?
5. What challenges to the port do you see if:
 - a. A ship gets delayed.
 - b. Cargo does not arrive on time to be picked up by a transporter at the terminal.
6. What are your thoughts of using DT simulation model to optimize port efficiency?

Terminal operator – vessel scheduling

1. Can you describe work processes and responsibilities as terminal operator?
2. Can you describe the process in vessel scheduling?
 - a. How do you plan vessel berth allocation (ETA and ETD)? Do you use AIS data in vessel scheduling?
 - b. When do you get the information of ships ETA, so that vessel scheduling could be done?
 - c. What's the minimum time ETA informed to cargo customer?
 - d. Does terminal keep track of ships real – time? If yes, how?
 - e. Handling scheduling due to delays because of reasons such as weather uncertainty, machinery failure?
3. How do you track of vessel turnaround time?
4. What are your views on using AI and machine learning in optimizing the vessel scheduling? What are your thoughts on using of DT simulation model for optimizing port efficiency?

Terminal operator – cargo operations (loading/discharging)

- 1 Can you describe work processes and responsibilities in cargo operations?
- 2 Can you describe the process of cargo planning system?
 - a. When do you start to plan for cargo stowage?
 - b. In planning are stevedores- allocated for different type of cargo?

3. Can you describe processes used in handling of cargo?
 - a. Is unloaded cargo transferred to storage area or directly leaves the terminal?
 - b. Is export cargo stored at the storage area or directly loaded on ship?
 - c. Which type of cargo (trucks, trailers or cars) takes longer time for loading/unloading?
4. How do you handle challenges such as port congestion?
5. Do you require/ use real – time information to assess the challenges?
6. How do you track and trace cargo for a goods owner? Incl. time for loading/discharging?
7. What are your views on using AI and machine learning in optimizing the cargo operations? What are your thoughts on using of DT simulation model for optimizing port efficiency?

Terminal operator – cargo allocation at yard

7. Can you describe your work processes and responsibilities as terminal operator in cargo allocation?
8. Can you describe the process of cargo allocation?
 - a. How do you plan the cargo allocation for each specific ship?
 - b. How early cargo arrive at the Ro-Ro terminal to be stored at the yard?
 - c. Do you use a Yard Management System (YMS) in allocation of cargo? Yes/No
9. How do you monitor and track cargo in real – time? for Dwell time?
10. What are your views on using AI and machine learning in optimizing the cargo allocation? What are your thoughts on using of DT simulation model for optimizing port efficiency?

IT manager

1. Can you describe work processes and responsibilities as an IT manager in the terminal operations?
2. Can you briefly describe the technologies being used in the terminal operation?
3. How do you handle the challenges with new technologies?
4. Which sensors are used in port logistics operations for collection of data about goods? Bar code, Magnetic ID, RFID for cargo? Other?
5. Can you describe how scheduling, cargo loading/discharging, cargo allocation done using IT?
6. How do you describe real-time data collection for port optimization?
7. What are your views on using AI and machine learning to predict traffic patterns and cargo handling times? What are your thoughts on using of DT simulation model for optimizing port efficiency?

Ships Officer – Stowage plan and vessel scheduling

1. Can you describe work processes and responsibilities as a ships officer in ship operations
2. How do you report Estimated time of arrival (ETA):
 - a. Manually at entering berth
 - b. Automatically at entering berth
 - c. At any time interval?

3. How do you consider slow steaming? i.e going with reduced speed to reduce emissions
4. How are ship delays in arriving the loading port managed?
5. How is the vessel scheduling conducted?
6. How is the cargo stowage plan made onboard?
7. How is the stowage plan coordinated with the terminal operator?
8. How do you handle unpredictable changes at last minute? E.g., if the cargo does not arrive on time, and you must make changes in stowage plan considering ship's stability?
9. Please rate 1-5, which operation takes more time
 - a. Arrival
 - b. Departure
10. What are your views on using AI and machine learning to predict traffic patterns and cargo handling times? What are your thoughts on using of DT simulation model for optimizing port efficiency?

Stevedores & Dockworkers In charge

1. Can you describe your work processes and responsibilities in terminal operation?
 - a. Who is responsible for cargo lashing and unlashng?
 - b. Is the time for stevedoring calculated? If yes how? For what purpose, predictive analysis?
2. Can you share the challenges in work scheduling of stevedore? i.e. sick leave.
3. How do you get the information as which cargo to be unloaded or loaded?
 - a. Type of cargo?
 - b. The sequence used in loading of cargo. Prioritised?
 - c. Do you have access to information on handling of cargo from the departing port?
4. What are your views on using AI and machine learning to predict stevedoring times? What are your thoughts on using of DT simulation model for optimizing port efficiency?

Sub Questions

1. Do you keep a record of turnaround time, cargo loading/discharging time, cargo dwell time in digital form?
2. What are the challenges faced by the port when ship gets delayed?
3. What are the challenges faced by the port when cargo does not arrive on time for loading or customer doesn't pick up the cargo from port?
4. Does the Ro-Ro terminal have a dedicated location for unloaded cargo and the cargo to be loaded?
5. What type of configuration of ramp of this ship? (Bow, stern quarter, side, and stern).