UNIVERSITY OF TURKU
Turku School of Economics

Evolving automatic identification system (AIS) in maritime

Future developments of AIS data

Information Systems Science
Master's thesis

Author:
Emma Seppä

Supervisor:
D.Sc Marikka Heikkilä

07.03.2024
Turku

Master's thesis

Subject: Information system science
Author: Emma Seppä
Title: Evolving Automatic Identification System (AIS) in maritime
Supervisor: D.Sc Marikka Heikkilä
Number of pages: 78 pages + appendices 8 pages
Date: 07.03.2024

Automatic identification system was initially developed to improve safety and situational awareness at sea and coastal areas. However, with the advancements in technology and the growth of the maritime industry, the potential uses of AIS data have expanded beyond navigation and safety. This thesis researches the potential future uses of AIS data and technical limitations of AIS through a case study. Previous studies include technical studies of AIS system and data quality. However, there is clear research gap observing the outcoming trends and how they affect AIS development.

The research identifies and studies the limitations and challenges relating to for example data accuracy, data quality and data access in using AIS data for business purposes. The study also highlights the future opportunities and benefits of using AIS for different stakeholders, such as port authorities, shipping companies, and environmental organizations. The research was conducted as qualitative research. First, the literature review studies the findings of previous research. The data collection method for this thesis was semi structured interviews. The interviewees were representatives of maritime field focused companies that use AIS data at their businesses.

The results of this research revealed that new AIS data usages are driven by safety, financial and legislative requirements. Also, the future new usages of AIS data align with the megatrends in maritime presented in the literature review. The results also highlight that while VDES technology shows promise in addressing technical limitations of AIS, it cannot overcome human-related limitations. The complete implementation is VDES is expected to take several more years, posing challenges for the maritime sector. Overall results emphasize the driving forces behind AIS data usages and the impact of VDES implementation on addressing technical limitations.

The study concludes that AIS data has the potential to provide valuable insights and support decision-making processes beyond navigation and safety. However, to unlock the full potential of AIS data, there is a need for collaboration between different stakeholders by ensuring open sourcing mindset to gain better data quality and accuracy.

Key words: AIS, automatic identification system, maritime, data-based business, autonomous maritime, smart maritime, VDES

Pro gradu -tutkielma

Oppiaine: Tietojärjestelmätiede
Tekijä: Emma Seppä
Otsikko: Kehittyvä automaattinen tunnistusjärjestelmä (AIS) merenkulussa
Ohjaaja: D.Sc Marikka Heikkilä
Sivumäärä: 78 sivua + liitteet 8 sivua
Päivämäärä: 07.03.2024

Automaattinen tunnistusjärjestelmä (AIS) kehitettiin alun perin parantamaan turvallisuutta ja tilannetietoisuutta merellä ja rannikkoalueilla. Tekniikan kehityksen ja merenkulkualan kasvun myötä AIS-tietojen käyttömahdollisuudet ovat kuitenkin laajentuneet navigoinnin ja turvallisuuden ulkopuolelle. Tämä tutkielma tutkii tapaustutkimuksen avulla AIS-tietojen mahdollisia tulevia käyttötarkoituksia ja AIS:n teknisiä rajoituksia tapaustutkimuksen avulla. Aikaisemmat tutkimukset sisältävät suurimmaksi osaksi teknistä tutkimusta AIS-järjestelmästä ja sen tuottaman tiedon laadusta. Alalla on kuitenkin selvä tutkimusaukko tarkastella tulevia trendejä ja niiden vaikutusta AIS:n kehittymiseen.

Tutkimuksessa tarkastellaan AIS-tietojen käyttöä yritysten liiketoiminnallisiin tarkoituksiin. Tutkimuksessa lisäksi tunnistetaan liiketoiminnallisiin tarkoituksiin vaikuttavia rajoituksia ja haasteita esimerkiksi tiedon laadun ja saatavuuden kannalta. Tutkimuksessa keskitytään myös miten eri sidosryhmät kuten satamaviranomaiset, merenkulun yritykset ja ympäristöjärjestöt voivat hyötyä tulevaisuuden mahdollisuuksista mitä AIS tarjoaa. Tutkimus suoritettiin laadullisena tutkimuksena. Tutkimuksen kirjallisuuskatsauksessa esitellään aikaisempien tutkimusten löydöksiä aiheesta ja pohjustetaan täten laadullista tutkimusta. Laadullisessa tutkimuksessa datan keruumenetelmäksi valikoitui puolistrukturoidut haastattelut. Haastateltavat henkilöt edustivat merenkulun alaan keskittyneitä yrityksiä, joilla oli käytössä AIS-tietoja liiketoiminnassaan.

Tämän tutkimuksen tulokset osoittavat, että uudet mahdolliset AIS-tietojen liiketoiminnalliset mahdollisuudet ovat suurimmaksi osaksi yhteydessä turvallisuuteen, talouteen ja lainsäädännöllisiin muutoksiin ja tekijöihin perustuen. Täten tutkimus lisäksi osoittaa, että uudet mahdolliset käyttötarkoitukset ovat linjassa kirjallisuuskatsauksessa esitettyjen megatrendien kanssa. Tuloksista voidaan myös todeta, että vaikka VDES teknologia näyttääkin lupaavalta ratkaisulta AIS:n teknisiin rajoituksiin, se ei voi voittaa AIS-tietojen inhimillisiä rajoituksia. Lisäksi VDES teknologian täydellinen käyttöönotto odotetaan vievän useita vuosia, mikä osaltaan asettaa haasteita merenkulkualalle. Kokonaisuudessaan tutkimuksen tulokset korostavat tulevaisuuden AIS-tietojen liiketoiminnallisten käyttötarkoituksien taustalla piileviä tekijöitä ja VDES:n käyttöönoton positiivisia vaikutuksia aikaisempiin teknisiin rajoituksiin.

Tutkimuksessa tullaan lopputulokseen, että AIS-tiedoilla on potentiaalia tarjota arvokasta päätöksenteon tukea navigointiin, turvallisuuteen ja moniin muihin aihealueisiin liittyen. Kuitenkin AIS-tietojen täyden potentiaalin hyödyntäminen tulevaisuudessa vaatii yhteistyötä eri sidosryhmiltä varmistamalla muun muassa avoimen tiedonjaon paremman tiedon laadun ja tarkkuuden varmistamiseksi.

Avainsanat: AIS, automaattinen tunnistusjärjestelmä, merenkulku, datapohjainen liiketoiminta, automaattinen merenkulku, älykäs meriliikenne, VDES

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

ACM	Adaptive Coding and Modulation
AIS	Autonomous Identification System
ASM	Application Specific Messages
AtoN	Aids to Navigation
BIIT	Built-In Integrity Test
COG	Course over Ground
CPU	Central Processing Unit
DGNSS	Differential Global Navigation Satellite System
EPIRB	Emergency Position Indicator Radio Beacon
ETA	Estimated Time of Arrival
GMSK	Gaussian Minimum Shift keying
GPS	Global Positioning System
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IHO	International Hydrographic Organization
IMO	International Maritime Organization
IoT	Internet of Things
ITU	International Telecommunication Union
LR-AIS	Long Range Autonomous Identification System
MMSI	Maritime Mobile Service Identity
MOB	Man Over-board
MSK	Minimum Shift Keying
OPA 90	Oil Pollution Act
PKC	Public Key Cryptography
ROT	Rate of Turn
SART	Search and Rescue Transponder
SAT	Satellite Links
SOTDMA	Self-Organized Time Division Multiple Access
TDMA	Time Division Multiple Access
TER	Terrestrial Links
VDE	Very High Frequency Data Exchange
VDES	Very High Frequency Data Exchange System
VHF	Very High Frequency
VTS	Vessel Traffic Service

1 Introduction

1.1 Introduction to the topic

In 1989 in Prince William Sound, Alaska coastline, tanker named Exxon Valdez crashed when running aground. This caused the biggest crude oil spill ever seen before in the United States. Even though, the cause of the incident was not only navigational error, nevertheless, discussion about situational awareness and vessel tracking began. (Stephens, 1994.) These events urged the Americans to launch an act called Oil Pollution Act (OPA 90) in 1990. OPA 90 demanded United States Coast Guard to start a study about using Vessel Traffic System in certain watercrafts and around specific port areas. (Wood, 1995.) Global Positioning System (GPS) was implemented in maritime and the development of new fully operational vessel tracking system started. (Stephens, 1994.)

AIS was generated in the 1990s to be a communication system which allows information to travel from vessel to vessel, vessel to land and from land to vessel through two Very High Frequency (VHF) radio channels. Each channel has 1-minute-long spaces which are built of 2250 slots. AIS receivers automatically choose which slot to use for the message. There are two types of AIS transceivers class A and class B. Class A transceivers transmit information more often and with bigger priority than Class B transceivers. Typically, Class B transceiver systems are simplified, and therefore many smaller watercrafts use Class B transceivers. In turn, class A transceivers usually have a screen for the AIS data and other advanced features compared to Class B systems. (Schwehr, 2011.) AIS data usually includes information for example on maritime mobile service identity number (MMSI), speed, and position. However, AIS messages can also include messages that are manually added for example estimated time of arrival (ETA). (Svanberg et al., 2019.)

The purpose of AIS is to transmit and collect information about watercrafts. The initial need for the system was due the lack of safety and situational awareness at sea and coastal areas. (U.S Committee on the Marine Transportation System, 2019.) Hence, in 1998 new performance standards were recommended for AIS by International Maritime Organization (IMO) to clarify and define the requirements of information provided by AIS and the technical tools to build AIS. These standards were implemented that AIS could be operating effectively to improve safety and navigation of watercrafts. (IMO, 1998.) Later, in 2002 IMO made it obligatory to install AIS to any watercrafts over 300 gross tonnage and to all passenger ships regardless of size. (U.S Committee on the Marine Transportation System, 2019.) At first, the AIS information flow was limited to VHF range which is around 10-20 nautical miles but after 2008 AIS receivers were built to satellites. Since then, the information has been available all around the world. (Yang et al., 2019.) Satellites enable the use of long-range AIS (LR-AIS) that uses communication satellites to transmit messages (IMO, 2015). In 2017 AIS verification service online tool became available for the stakeholders and for the public. This was supposed to make evaluating of AIS data easier and AIS data in general more reliable. (U.S Committee on the Marine Transportation System, 2019.)

Over time the international maritime transport and maritime technology has experienced consistent growth. Robotics, automation, smart ships, maritime safety, smart ports, and cybersecurity are part of everyday maritime. (Doumbia-Henry, 2018.) To add, IoT technologies, big data, virtual reality, augmented reality, cloud computing and 3D printing are technologies that obtain a big focus in the development of maritime sector (Plaza-Hernández et al., 2020). The developments in the sector influence over all changes in every aspect and technology must keep evolving with the current changes (Doumbia-Henry, 2018). Nowadays, AIS data is being used in different applications and intended uses. Many websites such as Marine Traffic, FleetMon, AISHub and APRS offer access to AIS data and vessel tracking data for everyone to see. (Tu et al., 2018.) In the figure 1 we can see a screen shot of the visualisation of AIS data on Marine Traffic's website. The passenger ship called Europalink is selected in the figure. After selection the website offers AIS information for example name, position, destination, and speed of the chosen vessel. This data is available online for everyone to see and try.

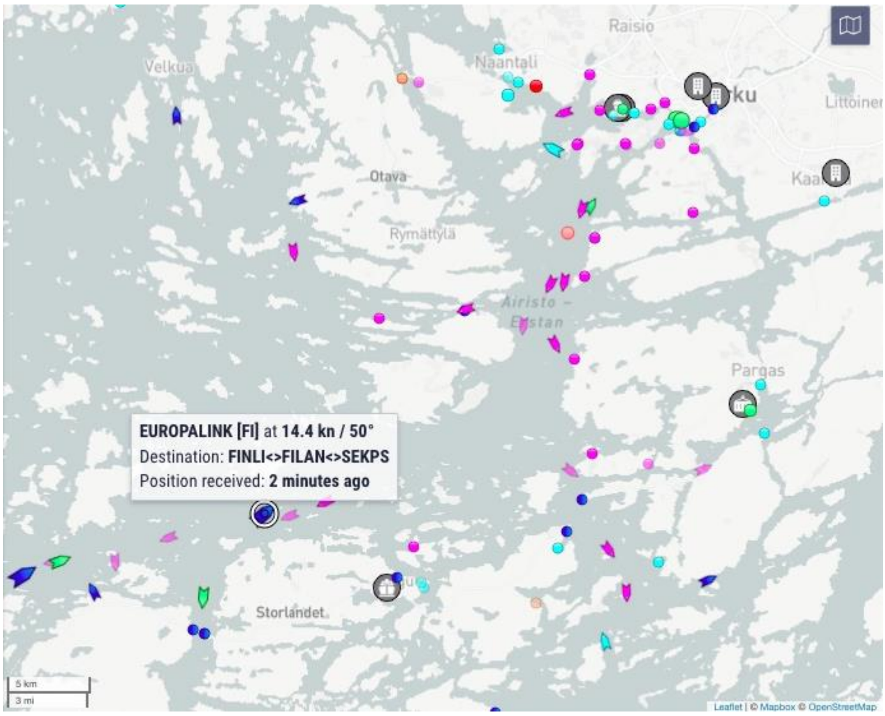

Figure 1 Ship tracking live map on Marine Traffic's website (https://www.marinetraffic.com)

1.2 Research gap

New requirements and constant development of AIS data mean that the data is being also used in other than navigation and safety related purposes (Yang etc., 2019). As you can see from the figure 2 the AIS data provides opportunities to visualize, store, collect, analyse, and distribute the data. After managing the data, it can be used to many different applications for example track the vessels and secure port areas. Also, businesses can use the data to enhance the efficiency of cargo shipments. So, there are plenty of new different usages for the AIS data. (EunSu et al., 2019) For the visualization of the aim of this thesis outside layer represents the possible future uses of data.

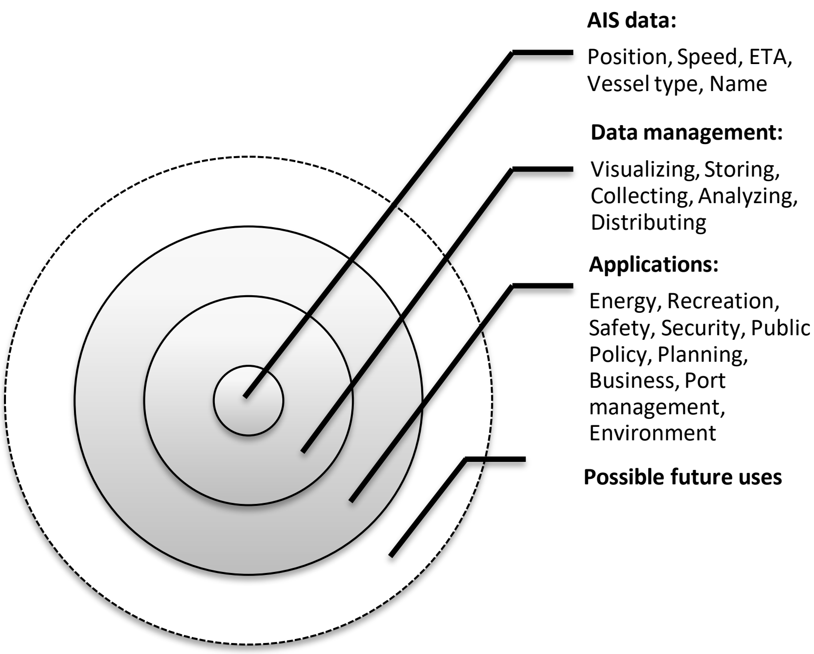

Figure 2 Uses of AIS data (EunSu et al., 2019) and edited outside layer of future uses.

Previously AIS was used for navigation purposes to avoid collision but now AIS is being used in multiple other purposes for example traffic and performance monitoring, emission controlling and intelligent navigation. (Yang et al., 2019.) For example, one of the current uses of AIS data is evaluating vessels' impact on environment (Winther et al., 2014). Historical AIS data is also currently being used to predict vessel movements, position, routes, marine traffic patterns and to choose the most efficient routes. (Pallotta et al. 2014). Since, AIS data is being used in various new applications the question rises about how the AIS technology and data should change to keep up with the new needs and requirements of the end users. This thesis plans to further clarify the upcoming developments, outside requirements, and needed technical updates of AIS.

AIS data and system have been widely researched in several research purposes because of the data's multiple usage possibilities. Also, many stakeholders can benefit from the AIS research and therefore the subject is an interesting research area and widely studied. Furthermore, AIS data enables studies in different fields. For example, the data has given the possibility to study maritime accidents, the geographical mapping of marine traffic and fishing patterns. (Svanberg et al., 2019.) The interest within researchers towards AIS has grown significantly. In Meyers et al., (2021) bibliometric research of AIS studies only few studies were identified between years of 1990 and 2000. However, after mid 2000s the number of studies has grown reaching around 140 research in 2019. Overall, it can be seen that the technological development of AIS is of interest to researchers and private sector. For example, AIS data can act as a foundation for maritime data analytics and AI development. This has created an urge for different parties to research AIS system and data. The urge for academic and private sector research can be also motivated by new technologies, changes in the technological environment and new governmental priorities. (Meyers et al., 2021.) It can be noticed that AIS related research covers mostly research about vessel collision, data anomalies, and predicting ship behaviour.

However, Svanberg et al. (2019) points out that there is clear research gap observing the outcoming trends and how they affect AIS data and AIS development. Also, there is still research gap relating combining AIS data with other sources (Svanberg et al., 2019). Moreover, new technological changes like VDES are coming regarding AIS. VDES is reasonably new technical change but few researchers within the last few years have been published about it. However, VDES still being in the testing phase so new studies on it are in need. Mostly research regarding VDES is technical and focuses on the technical changes and improvements of the technology. Therefore, qualitative research about the future usages, current limitations and required features of AIS aims to fill the current research gap in the field. Also, studying the different usages and applications of AIS data and focusing on its future developments will aim to contribute to bring knowledge about businesses point of view to the AIS discussion.

1.3 Research question

The research area of this thesis is evolving AIS in maritime. The aim of the research is to find out the current uses of AIS data and its current best practices, challenges, and technical limitations. The research will also discuss the upcoming developments and modifications of AIS. The aim is to scan different current uses of the data in the maritime sector to study the current limitations of AIS data. The research also will try to find out what the future uses of the AIS data could be. This includes researching how AIS data and technology should develop and how it can be applied to future uses. Research will discuss what are the best practices now and what practices create value for the businesses. Furthermore, what practices need to be developed further so that the AIS data can be used efficiently. Overall, the aim is to find out what is needed from the next generation AIS in the future. The research is executed as qualitative research and as a case study studying AIS as evolving phenomenon. The data was gathered by interviewing chosen companies that use AIS data in their business to gain knowledge about their current uses of AIS data and the upcoming needs, requirements, and developments of AIS data.

Research questions are listed below:

What are the current uses and applications, best practices, and challenges of AIS?

What are the future potential uses/applications of AIS, and how AIS data format and configurations will impact future services?

The first research question will be answered mostly with theoretical research and literature review. The literature review will define AIS as a system, its characteristics, and the current limitations of AIS. The literature review will also study maritime sector and the current applications of AIS, data in maritime. Then, the second research question will be mainly answered by interviewing companies about their AIS data applications and uses to find best practices of value creation and different development points for AIS data and AIS technology. The interviews are conducted as a semi structured interviews with the framework PESTE to help focusing on the future developments of AIS. The results chapter presents the findings of empirical data gathering. Lastly, discussion and conclusion combine literature and empirical material together to present further conclusions and findings of the research.

1.4 Theoretical framework

The theoretical framework consists of the chosen primary sections of the literature review. The purpose of theoretical framework is to illustrate and guide the literature review and research of theoretical material and to gain required information for the empirical part of this research. The theoretical framework of this thesis is modelled below in the figure 3. The arrows represent the associations between the factors. The main components and key contents in the theoretical framework are firstly satellite and vehicle AIS data from the system. Second components are the AIS data and formatting restrictions and limitations focusing on studying the data quality. Next, overall change in the maritime industry affects the future developments and usages so therefore megatrends are presented as an active part in the process. When researching AIS data usages in businesses data-based business models must be included since they affect the business usages of data. Lastly, the theoretical framework combines the megatrends of maritime, technical limitations of AIS data, data-based business models and current uses of AIS to examine future usages and possibilities of it. The created theoretical framework will work as a frame to create the theoretical literature research to answer the research questions above.

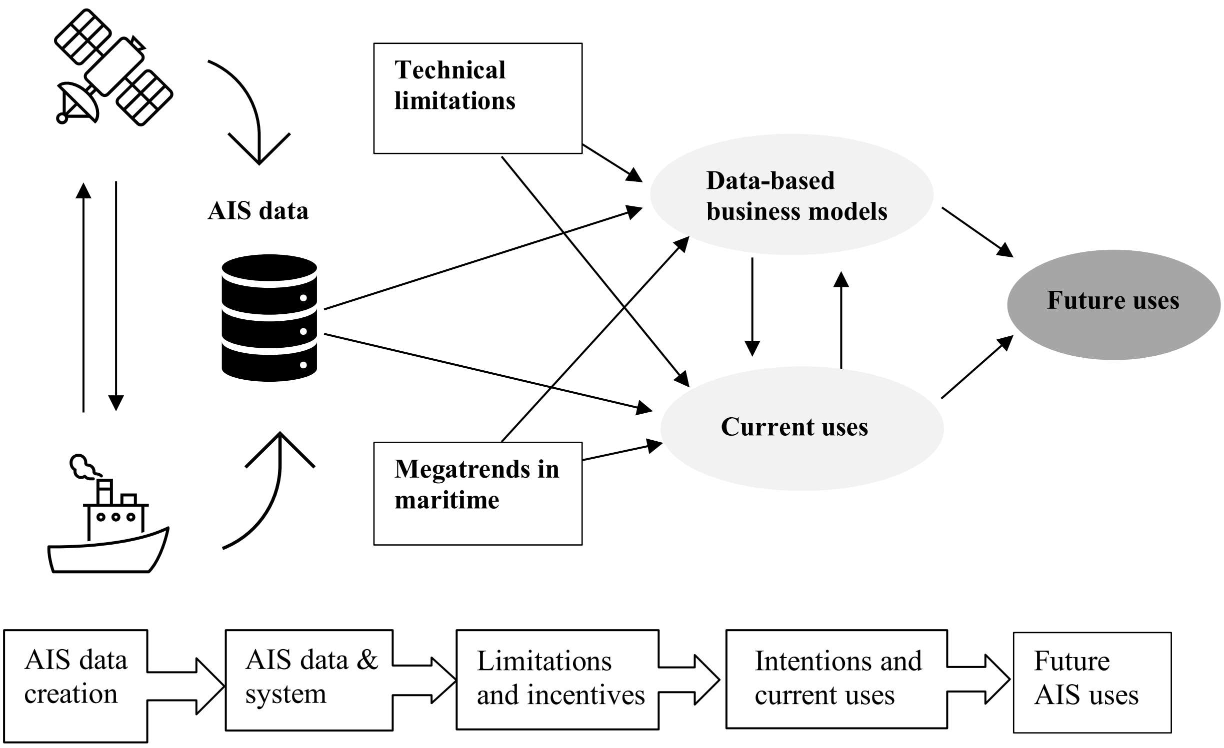

Figure 3 Theoretical framework

The Delone and Mclean (2003) IS success model is a framework that measures system success or effectiveness. The framework measures the successfulness of used IS system in a specific context. The framework has worked as a background theory assessing the AIS system when conducting theoretical framework for the research. The IS success model begins with evaluating the system quality and moves on to evaluating current use of system and user satisfaction. It then combines these success factors to evaluate net benefits or negative net benefits of the system. One part of the model is to consider the quality of a system. In this research we will be assessing the AIS data quality to evaluate AIS system. The framework also evaluates user satisfaction and current use of the system as AIS current uses are also studied. However, the IS success model works just as a background when conducting the theoretical framework and the model is not directly the basis of the theoretical framework. Delone and Mclean (2003) emphasise that different measures should be examined based on the system used and therefore when examining AIS, we will be also studying other factors that are not motivated by the IS success model. The model fits to the context of this research since AIS data quality and current uses are assessed and overall benefits of new future uses profit the whole maritime network.

(Delone & McLean, 2003.) The IS success model is presented below in the figure 4. The arrows represent associations between the key elements.

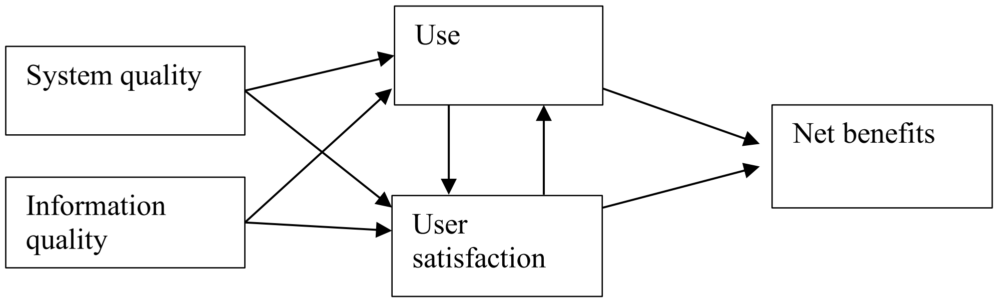

Figure 4 IS success model (Delone & McLean, 2003)

The definitions of each of the factors is presented in the table 1 below. This study uses IS success model to create theoretical framework to assess the successfulness and net benefits of AIS.

Table 1 Definitions of IS success model

IS success model factor	**Definition in the context of AIS**
System quality	Evaluating the technical limitations
Information quality	Measuring the AIS data accuracy
Use	Studying current and potential uses of AIS
User satisfaction	Evaluating if the technical aspects meet the potential uses of AIS
Net benefits	Concluding the net benefits of AIS in maritime field

2 Theory and literature

2.1 Automatic identification system

2.1.1 Overview of AIS

Automatic Identification System (AIS) is a system for exchanging navigational information and it was initially designed to help traffic control and to avoid impact with other vessels (Goudossis & Katsikas, 2019). IMO targets of AIS are safety and environmental protection through automatic navigational improvements (Harati-Mokhtari et al., 2007). Another motivation for creating AIS was the ability for the coastal authorities to monitor vessel traffic near the area and in that way improve national and coastal security. The initial purpose of AIS is to be able to detect other ships position with AIS through VHF channels. (U.S. Committee on the Marine Transportation System, 2019.) IMO (2015) states that purpose of AIS is to send vessel's data to VTS stations, SART stations, ATON stations, and other ships around. On top of navigational data, AIS allows to identify other vessels and send tailored messages through the chosen channels. It is seen that one of the main advantages of AIS information is that the data is accessible to everyone. (U.S. Committee on the Marine Transportation System, 2019.)

The AIS transmitters were made mandatory by IMO in 2002 to create safety at sea (U.S. Committee on the Marine Transportation System, 2019). Therefore, all vessels over 300 gross tonnage, cargo ships over 500 gross tonnage and passenger vessels are regulated by Safety of Life at Sea (SOLAS) to fit AIS A class transmitter onto the vessel. (Androjna et al.,2021.) Smaller ships for example sailboats and fishing boats are not required to fit AIS on board. However, they can fit and carry AIS if felt necessary. Therefore, many of the ships outside the AIS regulation range use for example B class transmitters (Schwehr, 2011.) Class B transmitters transmit messages at a less frequent pace and the use is not regulated (IMO, 2015).

AIS system works automatically, and it means that the devices transmit information autonomously in real-time to other ships and to shore on two different VHF channels. (Harati-Mokhtari et al., 2007.) AIS uses two designated VHF channels AIS1 channel on frequency 161,975MHz and AIS2 channel on frequency 162,025MHz. All the message transmissions happen on the VHF band. (ITU-R, 2014.) The bandwidth is shared to AIS users by technique called time division multiple access (TDMA). Each of the channels' bandwidth is then divided into 1-minute spaces with 2250 slots. After that, slots are determined to users using allocation system. The typical AIS messages take up one slot. (Wimpenny et al. 2022.) Automatic system means that AIS data is transmitted without a pause and continues to update information without interruptions. The transmission happens in a designated transmit interval. If the specific two channels are not available regionally, the AIS can be switched to alternative VHF channels. (IMO, 2015.) AIS sends different types of messages with other ships and shore for example about position and time of arrival through VHF. VHF channels are more convenient in situations where the radar cannot see other vessels due to obstacles or weather conditions at sea. Through VHF channels vessel can detect information about other vessels around hills and around other obstacles within the message range. (Harati-Mokhtari et al., 2007.) The range changes according to the antenna position, antenna height and other devices strengthening the range but estimate of average range is around 20 to 30 nautical miles (IMO, 2015).

2.1.2 Technical characteristics of AIS

AIS system uses Gaussian filtered minimum shift keying (GMSK) as the modulation scheme for message transmissions (ITU-R, 2014). GMSK is like minimum shift keying (MSK) modulation, but it has significant differences and the most noticeable one is that the gaussian modulation data or noise is distributed and shaped with gaussian filter. Graphically data or noise is shaped as a familiar gaussian diagram. Gaussian modulation determines the probability of data distribution to avoid changes in signals and ensure smooth waveform. Therefore, gaussian filter has a property of removing noise and signal details. (Singh & Vyas, 2020.)

AIS technical architecture is modelled below in figure 5. The architecture includes data from vessel's sensors that provide data for AIS for example speed sensors. Also, outside of the system are antennas which are presented outside of the system. Then, AIS itself has central processing unit (CPU), one transmitter, two multi-channel receivers and one 70 VHF receiver. These are presented in the central part of the image as part of the AIS system. AIS has also Global Navigation Satellite System (GNSS) receiver for satellite signal, built-in integrity test (BIIT) and display set which is used for accessing and inserting information to the system. That is presented as partly outside of the system since it is located at the interface. Then, there can be other optional graphical display sets outside of the actual system. (IMO, 2015.)

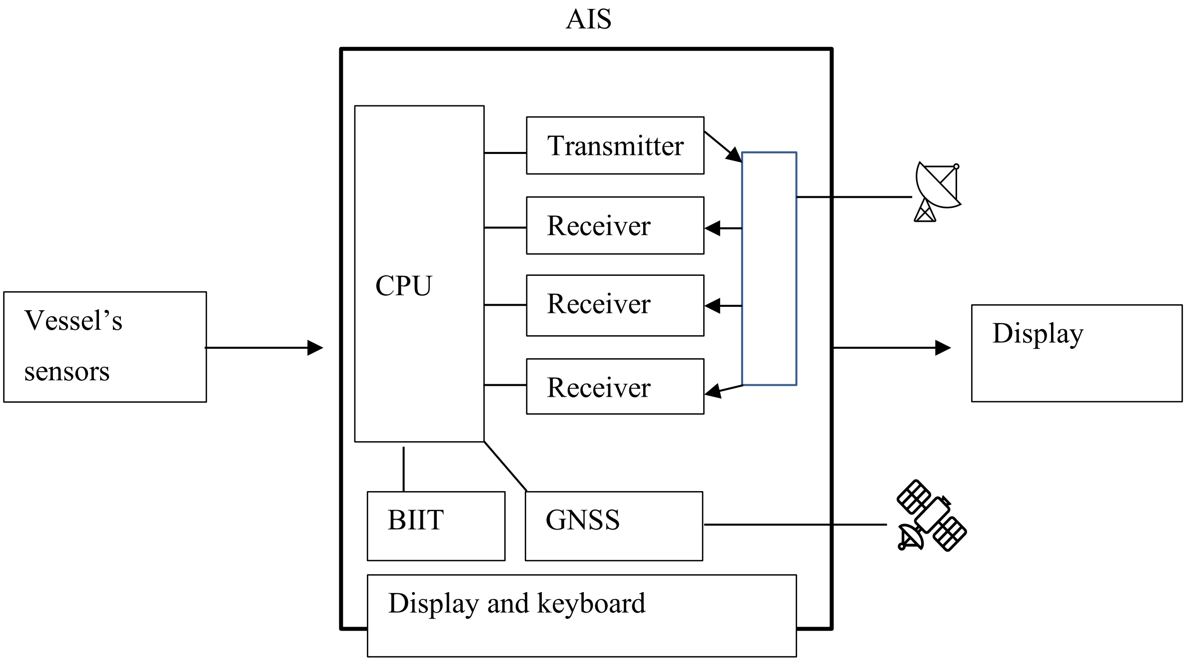

Figure 5 AIS architecture (IMO, 2015)

IMO has established core guidelines for AIS system to ensure uniform practices for AIS usage. AIS has two types of transmitters A and B, and they have different requirements by IMO. Class A follows IMO requirements, but class B transmitter has fewer qualities and therefore it does not have to fit IMO and SOLAS requirements. Broad AIS system overview of message flow between AIS stations has been modeled below in figure 6. As shown in the model vessels transmit their own data to each other and to Vessel Traffic Service (VTS) stations on shore. VTS station is modelled as the beacon at the bottom of the figure. This message flow between VTS and vessels is shown as a blue arrow describing the two-way communication. Vessels also receive data from other stations and other stations and equipment for example AIS-SART or AIS-ATON stations. These are modelled as the beacon at the left outer corner of the figure. SART only sends messages after being activated in safety situations. This message flow is modelled as an orange dotted line. (IMO, 2015.)

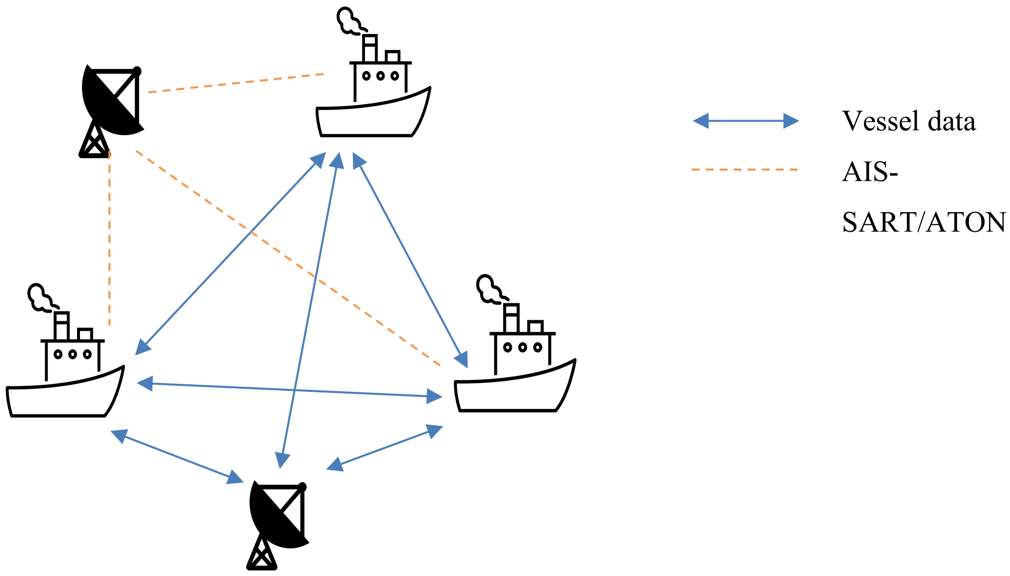

Figure 6 Overview of AIS (IMO, 2015)

AIS stations can be divided into two categories which are fixed stations and mobile stations. Fixed stations include Aids to Navigation (AtoN) stations and base stations then mobile stations include Class A and Class B transmitters, Man Over Boad (MOB), Search and Rescue Transmitter (SART) and Emergency Positioning Indicating Radio Beacon (EPIRB) tool stations. (Androjna et al., 2021.) AIS transmitters can be located on water for example buoys and SAR transponders. Also, they can be located on bridge of a vessel for example Class A and Class B transmitters or on shore for example VTS tower or lighthouse. (Balduzzi, Pasta & Wilhoit, 2014.)

2.1.3 AIS applications

Because of the automatic data transmission, the volume of the data is remarkably large which can make it difficult to analyse the data. For example, if data is transmitted every 2 seconds for one vessel, then that creates 1800 records per an hour for one vessel. It is estimated that for 5000 vessels in about three years 40 billion data records are generated. Raw AIS data is formed out of scattered points and only certain information can be directly extracted. The most used methods to analyse and mine AIS data are trajectory extraction, clustering, and prediction. Trajectory extraction refers to the vessel data that creates a pattern. Trajectory clustering means that similar data is clustered by discovering common trajectories with algorithms. Trajectory prediction can be done when extraction and clustering has been conducted and for example vessel's position can be predicted for a short-term. Extraction, clustering, and prediction work as a base so that AIS data can be used to predict vessel movements, detect anomalies and to avoid impact with other vessels. (Yang et al., 2019.)

The initial purpose of AIS is to assist vessels with navigation and avoid collision. Naturally, further applications have been created to enrich navigational safety. Few of these applications are for example to assess ship domain construction, assess impact risk of vessels, and voyage route planning. (Yang et al., 2019.) Ship's domain stands for the area of ships surroundings it should stay clear of. Simply saying it is the geometrical area around the ship. (Hörteborn et al., 2019.) Therefore, planning collision avoidance construction of ships domain is vital. Route planning application is also built from the data of domain construction and collision risk assessment so that vessel can choose route with the lowest risk of collision. (Yang et al., 2019.) Route planning applications are based on ant colony optimization which is an evolutionary algorithm that is originally inspired by ant behaviour and ant colonies. The algorithm uses heuristic data to create a solution for a problem. (Gómez & Barán, 2004.) Other safety tools are mobile AIS-SAR tools for example MOB, EPIRB and SART that utilize AIS data for the rescue operations by sending distress signals and coordinates when a person is in danger. These tools are created to improve safety at the sea. (Androjna et al., 2021.) Other safety inspired applications are for example based on anomaly detection that is compared to historical patterns of normal behaviour. This can be used to notice for example illegal activities. AIS data is also used to learn about maritime traffic patterns by trajectory prediction to aid and control high traffic areas to create transparency. (Yang et al., 2019.)

AIS data offers opportunities for other applications for example by analysing vessel behaviour. This can be used to detect illegal fishing activities and activities in restricted areas. (Yang et al., 2019.) Initially AIS gives an opportunity to detect and monitor fishing fleets and other parties involved in fishing. However, AIS device can be manually turned off and that way it can make monitoring tricky. Turning device off does not always mean illegal activities. Sometimes vessels turn off AIS to hide from pirates or to hide confidential fishing places. (Welch et al., 2022.) The massive amount of AIS data can be also utilized to analyse environmental effects of vessels. So, the data is used for example in emission control applications on board and to oil spill risk assessment and management tools. Also, by analysing high traffic routes data can be used to protect critical habitat areas and endangered species. (Yang et al., 2019.) Summarizing oil spills and heat maps, maps of the oil spill impacts can be conducted. Oil spill impact maps can also be compared to mappings of endangered species. With the help of these tools, assessments of oil spills impact to ecological factors can be made. (Wright et al., 2019.) To conclude, AIS data can be a big tool of analysis and foundation to environmental applications on board (Yang et al., 2019).

Lastly, in few years AIS data is also being used in advanced applications. These applications include trade analysing applications that track busy routes and model trade maps of the data. (Yang et al., 2019.) These applications utilize historic AIS data to create patterns and visualizations. Analysing historic data can be used to create heat maps of vessel traffic. (Wright et al., 2019.) Also, AIS data can be used in ship and port performance judgement applications that are used to optimise vessels' costs and performance around port areas. Another example of AIS data applications are arctic shipping applications that are designed to improve shipping safety by effective polar search and rescue. (Yang et al., 2019.) An accident around arctic areas can be catastrophic because of the remote location, rescue difficulties and rough and often changing environmental conditions. Therefore, AIS data products designed for arctic shipping informing and guiding ships around changing arctic environment were well needed. (Wright et al., 2019.)

2.2 AIS System restrictions

2.2.1 AIS messages

AIS has 27 message types (Molina et al., 2020). The messages can be divided to static and dynamic depending on how often the data is updated. Dynamic messages for example speed of the vessel and rate of turn are automatically updated and broadcasted more often than static data. Static data for example MMSI and vessel's name are usually manually added to the system and not changed during the voyage or not always after the voyage either. (Yang et al., 2019.) There are few examples of available AIS data received from AIS messages in the table 2 below. Type 1 to 3 messages are called dynamic messages and these messages include for example, speed and position. Dynamic message means that the data is updated automatically for example vessel's position is updated automatically. Type 5 messages are called semi-static or static messages because they are inserted manually. Static messages are only changed once and very rarely changed after that. Static and semi-static messages include for example MMSI, destination, ETA, watercraft's name, and type. (Svanberg et al., 2019.)

Table 2 AIS message types (Svanberg et al., 2019)

AIS Message Type	Field Name	Description
Type 1 to 3	MMSI	Identification number
	Navigation Status	Moving, at anchor, moored etc.
	Rate of Turn	How fast ship is turning
	SOG	Speed of ship Over Ground
	Position Accuracy	<10m or >10m
	Longitude & Latitude	In decimal degrees
	COG	Course Over Ground
	True Heading	In degrees
	Timestamp	Seconds of UTC minute
	Maneuver Indicator	Special maneuver: yes/no/available
Type 5	MMSI	Identification number
	IMO Number	Identification number of ship
	Call Sign	Ship radio call sign
	Vessel Name	Name
	Ship Type	Type
	Dimension to Bow	Distance: antenna to bow
	Dim. to Stern	Distance: antenna to stern
	Dim. to Port	Distance: antenna to port
	Dim. to Starboard	Distance: antenna to Starboard
	Position Fix Type	What system: GPS/Galileo /GLONASS etc.
	ETA	Estimated time of arrival
	Draught	Draught of ship
	Destination	Name of destination

One of the AIS messages is MMSI which is a 9 number unique identification code for each vessel's AIS. The number is typically manually added when AIS is installed to the vessel. Typically, there is no need to change this number after installing. Big problem with this identification number is that multiple times it might have been added incorrectly. Also, this may appear so that multiple vessels might have same identification number with each other if number is not added correctly. This affects the messages' reliability, and the vessel cannot be identified with this number. Also, it has been detected that in some cases MMSI numbers can swap between ships for a period if one vessel is at anchor and other on is passing by. These errors are probably system-based but can also be due to human error when implementing AIS. (Harati-Mokhtari et al., 2007.)

Vessel type is another static data from AIS. This data must be manually selected from the list of vessel types. Therefore, the vessel type might not be implemented or chosen correctly. Correct vessel type would increase user confidence in the system. However, vessel types vary between different AIS manufacturer's systems so there is no absolute coherent list of vessel types. AIS has also few limitations to vessel name field. The system limits messages to 20 characters and therefore names over the limit must be shortened or abbreviations must be used. Overall, all static data that must be implemented manually to AIS can have a certain amount of human error. (Harati-Mokhtari et al., 2007.)

Position is a dynamic an automatically updating information from AIS. Study has shown that in some cases vessels' position show latitudes more than 90 and longitude more than 180 which shows incorrect position. It is speculated that this is due to the positioning system not connecting to AIS properly. Many of AIS message related problems are due to the incorrect installation of the system and incorrect integration with other systems on the bridge. (Harati-Mokhtari et al., 2007.) Rate of turn is also considered dynamic data but usually it needs external indicator connected to AIS to return correct values. Rate of turn values are therefore not always reliable since indicator might not be correctly connected to AIS. (Rong et al., 2022.) Data providers also don't necessarily provide rate of turn (ROT) and course over ground (COG) values automatically. Therefore, for outside data user information entries can be blank if they are using certain data providers that don't provide necessary kinematic information. (Tu et al., 2018.)

2.2.2 Message range

Originally, the AIS message range is around 20 nautical miles because it is limited to VHF range at sea. (Goudossis & Katsikas, 2019.) Because of the limited amount of message slots, some messages could be dropped. The range also being considerably small, two vehicles that don't see each other might not receive each other's AIS position messages. Third parties for example aircrafts can also interfere the range making message flow difficult. (Golaya & Yogeswaran, 2018.)

After 2008 satellites were introduced to AIS and data could be received worldwide and it partially fixed the problem with short message range. Though, vessels still use AIS data on VHF range when coastal authorities use satellite-based data so that receivers are not overloaded. Also, when vessel is close enough to the shore it can use the shore antenna rather than rely on satellite. Still, data from satellite receivers is easily accessible worldwide for everyone through websites that gather AIS satellite data for example Marine Traffic. (Yang et al., 2019.)

However, satellite-based AIS has its difficulties. The most used antennae are static rod antenna. This was originally not designed for the use of receiving AIS data and therefore the device has its own limitations. One of the main issues detected due to the changing speed of the satellites is Doppler shift effect. (Golaya & Yogeswaran, 2018.) Doppler shift effect means that the frequency of the transmission changes according to the position and speed of the satellite. For example, when satellite is further away from ground the frequency reduces and when satellite comes closer to ground the frequency increases. (Ilčev, 2017.) One other issue with satellites is the larger radar of the satellites faced with the restricted slots of message transmits resulting in overlapping messages. Also, signals passing long range through ionosphere can possibly result in radio wave attenuation. Lastly, message collision was a result of different ranges from satellites. Meaning that even when messages were sent to different timeslots, they arrived concurrently because of the difference in satellite ranges resulting message collisions. (Golaya & Yogeswaran, 2018.)

It is estimated that just about 60%-80% of space-based AIS messages are detected. In the end, only way to decrease the message collision is to decrease the AIS channel message load. One idea could be that vessel's transmit their messages when a satellite is passing by. (Golaya & Yogeswaran, 2018.)

2.2.3 Message slots

AIS uses Self-Organized Time Division Multiple Access (SOTDMA) method for sending and choosing time for AIS messages on channels (Last, Hering-Bertram & Linsen, 2015). The VHF channels have a 1-minute spaces which consist of 2250 slots (Schwehr, 2011). AIS messages are transferred on two VHF channels on two frequencies 161.975 MHz and 162.025 MHz Therefore, on two channels the overall number of slots is max. 4500 per a minute. SOTDMA is a method that controls AIS message traffic on VHF channels.

The method works so that AIS devices automatically try to find free timeslot for the message. AIS device detects other AIS devices and then tries to find time for the data transmission. (Last, Hering-Bertram & Linsen, 2015.)

AIS transmitters sent location messages depending on the speed of the vessel. Vessels anchored or moored with AIS on, send location every three minutes. Vessels moving at a lower speed send location every 10 seconds, bigger speed vessels send it every six seconds and vessels with highest speed send location every two seconds. Transmitters A and B have different conditions for transmitting messages. AIS message transmission times are shown in a table 3 below. The table is divided to class A and class B transmitters. (Androjna et al., 2021.)

Table 3 AIS data transmission intervals (Androjna et al., 2021)

Ship conditions Class A	**Channel transmissions**
Anchor or moored	3min
SOG 0-14 knots	10 s
SOG 0-14 knots and changing	3.3 s
SOG 14-23 knots	6 s
SOG 14-23 knots and changing course	2 s
SOG > 23 knots	2 s

Ship conditions Class B	**Channel transmissions**
SOG < 2 knots	3 min
SOG > 2 knots	30 s
Ship static information	6 min

In busy ports and areas detecting AIS messages can become difficult due to message collisions. Message collisions can happen due to multiple transmissions within the same timeslot and therefore the messages might not go through. (Golaya & Yogeswaran, 2018.) In busy areas, some AIS devices might not find suitable timeslots and therefore the transmitted data might get lost (Last, Hering-Bertram & Linsen, 2015). The navigation application or system can look like in the figure 7 below which shows multiple vessels in the same area using AIS. This affects the data clarity, and the VHF channels could be overloaded and saturated because of the data amount. (Molina et al., 2020.)

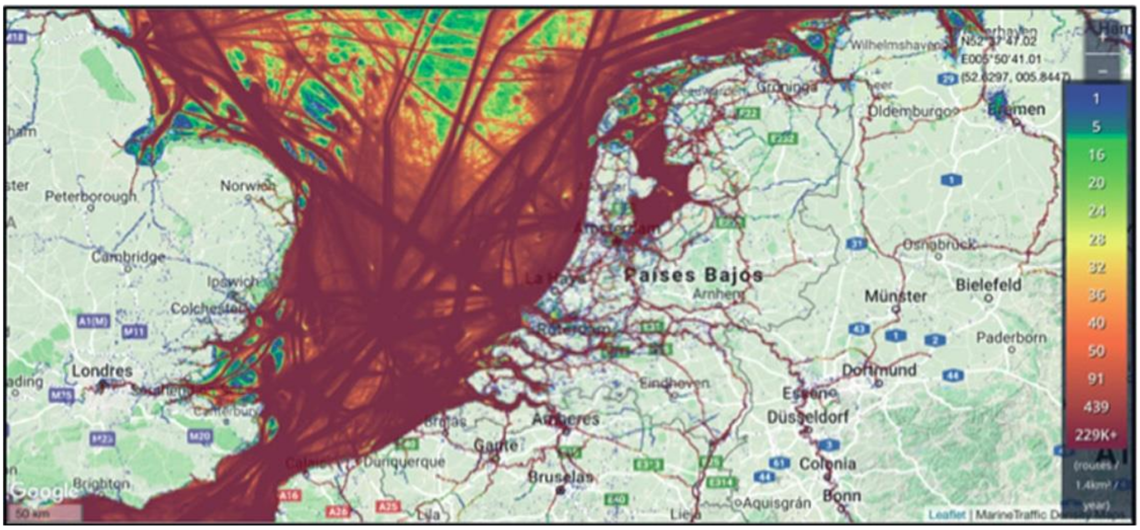

Figure 7 AIS overload in English Channel (Molina et al., 2020) (https://www.marinetraffic.com)

2.2.4 Security of AIS

AIS data is transmitted in VHF channels, and this broadcasted data might end up to malicious third parties. Free and easily accessible AIS data can put vessels and passengers to danger. (Goudossis & Katsikas, 2019.) Transmitting messages on VHF channels is one of the main advantages of AIS but it is also one of the main vulnerabilities since the system does not have cyber security. AIS's open-sourced system technology is weak for spoofing attempts and data corruption. Therefore, it is generally easy to criminals to create false signals. The main issue is that AIS does not have an adequate system security. AIS technology has not been developing with the threats of malicious cyber-attacks and therefore it has been left behind on the development of security. (Androjna et al., 2021.) AIS system initially does not have any cyber protection against attacks since the system was designed to be open to everyone (Wimpenny et al., 2022).

Spoofing can create dangerous situations in busy areas. For example, a vessel might try to avoid nonexistent vessel in a busy area endangering other vessels around. One of the main issues with spoofing is navigational data is not easy to verify. (Androjna et al., 2021.) Other serious cyber-attacks can be to re-route vessel's course and to spoof vessel's position. Also, misusage of AIS management messages to interfere with other AIS communicators. Potential attack can for example also be a mass attack to spoof nearby AtoNs' location to mask genuine AtoN that is performing illegal actions. (Wimpenny et al., 2022). When combatting against cyber-attacks we should first start with challenging manufacturers to only offer equipment that has been proven reliable. The equipment should be tested towards spoofing and attacks. However, massive capacity testing requires help from maritime sector, organizations and even government. What comes to the system, one of the upgrades to AIS could be encrypted signature techniques for the AIS data. Also, in navigation vessel should not blindly rely on AIS data and should compare the data to different sources so that the information can be verified. (Androjna et al., 2021.)

One solution to verify the source of the AIS messages can be to authenticate the original messages by using public key cryptography (PKC). This way AIS messages could be digitally signed offering prove for the receiver about the originality of the message. With PKC messages can be originated to actual sources and that way spoof messages could be detected. PKC uses key pair that is combination of a public and a private key. The public key is available for all users. The authentication of messages unfolds by the sender by encrypting the message with private key which is only open for the message sender. Then, the message can only be decrypted with the open key. This provides for the receiver the information about the original authenticator since the encryption can only be done with the private key. Recommended practice is to send the message openly and then sending authentication message alongside it. So, the digital signature could be sent in a separate message through VHF channels. However, some kind of timestamp of identifying mark must be included in the messages so that the receiver connects them to each other. Though, these signature messages have a significant impact on the AIS channel loads and AIS does not have enough bandwidth for routine digital signature messages. (Wimpenny et al., 2022.) Therefore, the messages should be small enough to be usable but still be large enough to provide needed security. By using certain algorithms like Elliptic Curve cryptographic algorithms signatures can be produced that fit to VHF based systems.

(Wimpenny et al., 2018.) New technologies like VHF data exchange system (VDES) provides an opportunity to carry digital signatures on the new side channels that don't intervene with AIS channels. However, this means that the receiver should have the required equipment for receiving the messages. (Wimpenny et al., 2022.)

2.2.5 Data quality

AIS messages can be false, they are relatively easy to spoof, and could be inserted incorrectly. When data is inputted incorrectly on purpose, it is falsification. Some of the date is inserted manually and there is an opportunity to falsify information to mask illegal activities. Destination masking and identity thefts are two type of data falsification. Vessel could for example falsify the identity of themselves to trade illegally with another vessel. AIS transponders can be manually turned off and there lies an opportunity to turn off destination and location. This created an opportunity to mask illegal activities when location is turned off. However, turning off AIS is not always linked to illegal activities since it is also a way to hide from pirates. Then, as discussed earlier, AIS messages are considerably easy to spoof. Spoofing happens from an external location and is indented to create false information to mislead potentially the crew and other vessels. (Iphar, Napoli & Ray, 2015.)

Human error, poor administration, and inaccurate AIS information can have a massive effect on the safety of the vessels. When data is not always reliable it affects the decision makers so that they cannot trust the data entirely. (Harati-Mokhtari et al., 2007.) One real life example is the collision between two vessels Hyundai Dominion and Sky Hope in 2004 which was partly resulted by poor usage of AIS and incorrect information sent by each party when using AIS messaging. (MAIB, 2005a.) Human-machine collaboration is vital part of AIS data reliability and quality. Correct input of data, introduction of technology, and training of system administration have vital impact on the performance of AIS. Training mariners to use AIS correctly could result in confidence boost to use the system in more dynamic way. Many of the data errors are caused by exclusion and input errors of data by humans. It is suggested that the system could be linked to other systems on bridge to check the inputted data and any inconsistencies in it. For example, linking the navigation status and the speed of a vessel together. This could be used so that a vessel moving at a high pace cannot have a navigational status moored. Some inconsistencies in data could be checked by integrating AIS onto the other systems on bridge. (Harati-Mokhtari et al., 2007.)

Data quality assessment depends on what type of data and on the amount of the data. One way to categorize data quality is divide that into external and internal quality. External meaning the quality that the user experiences which depends on the purpose of the use and internal meaning the technical view of the quality. AIS message quality dimensions that can be used to assess data quality can be divided to seven dimensions: accuracy, precision, reliability, currentness, completeness, consistency, and integrity. These dimensions can help to assess and evaluate the AIS data. Accuracy stands for the actual values and the accuracy of numeric data. In AIS context this could be evaluating the message data for example speed. Precision means the value rounding for example with coordinates more numbers mean more precise information. Reliability stands for the coherence of outside rules and data values for example that data is coherent with outside recommendations of ITU. Currentness addresses the fact that data value evaluates with time and data need to be repeatedly updated to stay accurate for example outdated location data does not serve the purpose of the information. Completeness represents the filled database and the completeness of all the attributes. Consistency represents the coherence of the data filled in a database so that the closely linked data is coherent and values agree with each other. Integrity combines all the previous dimensions and emphasizes the modifications to database to create a complete and up-to-date database. Data quality dimensions and their explanations are concluded in the table 4 below. (Iphar, Napoli & Ray, 2015.)

Table 4 Data quality evaluating dimensions (Iphar, Napoli & ray, 2015)

Quality dimension	Purpose
Accuracy	Actual values for example speed
Precision	Value rounding of coordinates
Reliability	Data coherent with outside standards
Currentness	Up to date data information
Completeness	Completely filled database
Consistency	Coherent values in database
Integrity	Combines the dimensions above

2.3 VHF data exchange system

2.3.1 New communication solution

New technology called VHF data exchange system (VDES) was introduced first time in 2013 by couple of organizations to fix and address the current issues with AIS in maritime (Molina et al., 2020). Initially, the huge population of original AIS generated new applications and need for specified data. The interest in not just location focused messages but also in other modified Application Specific Messages (ASM) that provide interesting data awoke. However, ASM messages overloaded AIS channels and therefore initial idea was to move ASM messages off the channels. As the ASM messages could not be allocated to other maritime applications the discussion and the concept of VDES arose. (Alagha and Loge, 2022.) Molina et al. (2020) also emphasizes that the channel overload and security problems triggered the talk about updates to the current AIS.

When talking about VDES, the concept needs to be well described since VDES has been described with diverse names. In some cases, the new system is referred as AIS 2.0. For example, Sternula A/S (2022) refers to AIS 2.0 when talking about VDES. However, more often system is described to be an evolution of the original AIS (Molina et al., 2020). In other sources VDES rather than being called upgraded version of AIS or AIS 2.0 is seen as a new communication solution. The new system combines AIS and other communication two-way data channels creating a system for vessels to communicate through terrestrial and satellite links globally. Old AIS system is therefore included in VDES and is one part of it. (Lázaro et al., 2019.)

2.3.2 VDES architecture

VDES is constructed of three components:

- Long Range AIS (LR-AIS),
- Application Specific Messages (ASM)
- VHF Data Exchange (VDE)

First component LR-AIS means extended AIS message ranges by using satellite links to messages from vessel to satellite. Then, ASM are different message types sent from vessels. Lastly, VDE is a system that enables high-rate data exchange. VDE consists of two options: VDE for Terrestrial Links (TER) and VDE for Satellite Links (SAT). (Molina et al., 2020.) Generally, AIS transfers safety and location related data of vessels but also transfers integrated data of AtoN, SART and MOB units (Lázaro et al., 2019). More specific and accessory data is transferred via ASM to help take load off the AIS channels. Lastly, VDE was designed for richer data since its bandwidth is larger. (Shijie et al., 2021.) VDE-TER and VDE-SAT have different frequency resources and they maximize together the system and their resources for the communication. VDE-SAT can be used when vessel is outside TER coverage and vice versa VDE-TER is the most efficient to use when vessel is near the terrestrial zone so near the coast area. Also, the system allows VDE-SAT to use the frequency resources that are left unused by TER. (Alagha and Loge, 2022.)

VDES offers large variety of message transmit options ship-to-ship, ship-to-shore, shore-to-ship, ship-to-satellite, and satellite-to-ship. The VDES aims to add two new channels for ASM messages. The purpose of this is to take off the load from the two original overloaded AIS channels. (Sun et al., 2022.) IMO-R (2022) has designated these channels to be 161.950 MHz and 162.00 0 MHz Also, additional 12 channels for VDE-TER messages are added to VDES entirety (Lázaro et al., 2019). 6 channels are for the uplink and 6 others for the downlink (IMO-R, 2022). The changes to the radio channel counts are presented in the table 5 below to get the visual of changes.

Table 5 Radio channel count (Molina et. al, 2020)

	AIS & LR-AIS	**ASM**	**VDE-TER**
Channel count	2	2	12

The modelling of VDES architecture is shown below in figure 8. It shows the different message transmit options and components. The arrows represent the message flow. Therefore, arrow on both ends represents two-way communication. VDE-SAT communication is also two-way. Long range AIS and VDE-SAT is only used for long distances between satellite and a vessel. As we can see in the figure AIS is one apart of the communication new system and VDES offers more options for message transfer and bandwidth. With the help of new communication options and two-way communication, we can say that message transmission gets more reliable.

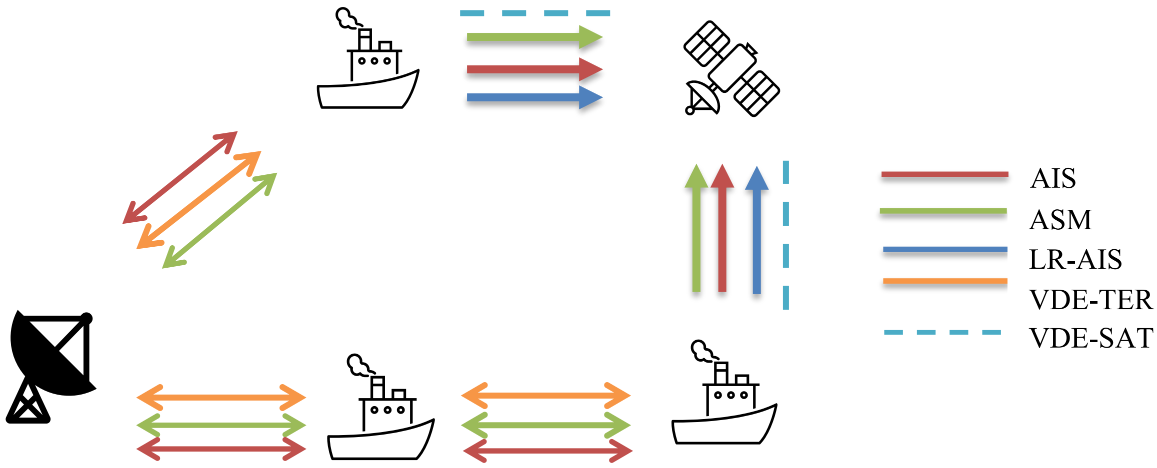

Figure 8 VDES architechture (Shijie et al., 2021)

One of the biggest improvements of VDES is the use of Adaptive Coding and Modulation (ACM) for transmissions. ACM technique consists of coding rate and the suitable modulation which are chosen in line with the experienced noise and detected link quality. Simply, the system adaptively chooses a best coding and modulation technique for a current situation. For example, when a vessel is further away, they might receive a poor signal that is just slightly stronger than the experienced noise. In this case, the transmitter chooses a modulation with high rate for the communication situation. When the vessel approaches the coast area and therefore the signal gets better, and noise weakens then less tense modulation and coding could be used for the situation. (Lázaro et al., 2019.) The VDES introduces three new modulation techniques for the VDE-TER: 8-PSK, π/4QPSK and 16-QAM when AIS and LR-AIS still use the previously used Gaussian filtered minimum shift keying (GMSK) modulation with no changes to it. (Molina et al., 2020). Table 6 below shows the different modulations of the components of VDES and changes in them comparing to AIS.

Table 6 Modulation of VDES components (Molina et al., 2020)

	AIS & LR-AIS	**ASM**	**VDE-TER**
Modulation	GMSK	GMSK, π/4QPSK	π/4QPSK, 8-PSK, 16-QAM

Furthermore, other initial improvement of VDES is the increase in capacity and frequency performance (Sun et al., 2022). Also, VDES allows new applications and more efficient signaling since there are many new technical improvements that come with it. The most required technical improvement is the increase in the communication channels. Also, the rate which signals are transmitted in a channel is improved because of the channels bandwidth is being largened. (Molina et al., 2020.) Since VDES allows larger data flows than regular AIS, signature messages through new channels could be sent to authenticate and track the origin of messages without overloading the channels. ASM offers and opportunity for authentication of high-risk messages. (Wimpenny et al., 2022.) Lastly, VDES can be used for various new applications including intelligent navigation, analysis of emissions and estimation of weather conditions (Molina et al., 2020). In the future one major improvement to VDES could be to use multiple antennas to increase the capacity even more (Lázaro et al., 2019).

2.3.3 Implementation of VDES

The implementation process and standardization of VDES is cautious and long lasting. First, the process starts with the standardization of VDES by International Telecommunication Union (ITU). Next, discussion and decisions about new radio frequencies need to be reviewed at the world radio communication conference. The radio frequencies need to be tested and standardized. (Lázaro et al., 2019.) Now we are at the point where ITU radiocommunication sector has released the recommendation ITU-R M.2092-1 for VDES in 2022 which describes the technical aspects of VDES. The recommendation also includes the new frequencies for ASM and VDE channels. (ITU-R, 2022.) This recommendation helps to give frames to the development work of VDES. Lastly, VDES should be made mandatory by authorities like IMO. Without IMO requirement the new transceivers would have to be low cost so that vessels would want to implement it. (Lázaro et al., 2019.)

The project of fully working VDES implementation is still ongoing. The implementation includes satellite testing and implementation of the VDES technology. The selected satellites are doing trial runs for the first quarter of 2023. After the successful testing the group of satellites will be dispatched. (RINA, 2022.) However, it is difficult to estimate the full time that the implementation of the VDES technology would take. Sternula A/S (2022), a Danish company that provides commercially satellites to VDES project estimates that the implementation project could take about 10 years because of the new transceiver has to be implemented manually to shore, buoys, and vessels.

VDES is expected to be in use within the next years but the implementation to the crew bridge can be difficult and requires training. (Molina et al., 2020.) The overall implementation process can take even longer since implementation problems can occur. Also, user implementation should always have a great importance in the implementation process. Equity-implementation Model suggests that end users calculate their inputs and the overall outcomes when technology is implemented. The end users in this case would be the people using VDES on board. Therefore, users consider factors like new workload, ease of use and possible job advancements when technology is implemented. So, if the new technology brings more improvements than workload and user input, users adopt the technology easier. (Kailash, 1991.) Other factors need to be also considered before implementing VDES. Questions like is there need for VDES, are there enough human resources and funds for the upcoming process of implementation need to be answered before implementing it to all shore stations and vessels. Another consideration of VDES implementation is the AIS system load in that area. If the system load is so that the number of slots used is under 50% no VDES is recommended. However, if system load is over 50% then VDES is recommended to implement. Factors of consideration are shown in the figure 9 below. The figure is a decision matrix which helps to determine whether to implement VDES and what factors to consider and whether to continue using only AIS and keeping situation otherwise under review. (IALA, 2017.)

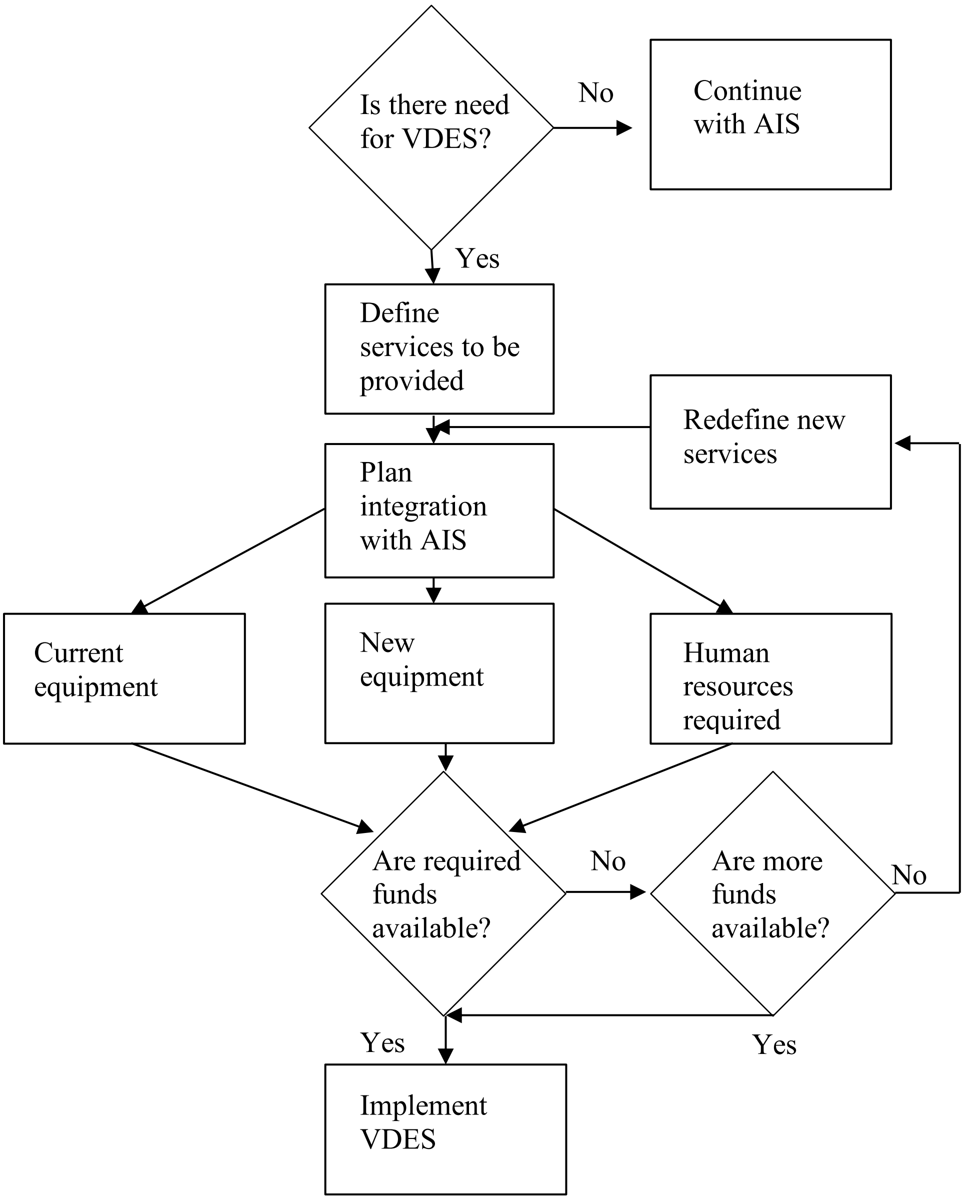

Figure 9 VDES implementation matrix (IALA, 2017)

2.4 Data-based business

2.4.1 Data-based business models

Data has become a big part of businesses since it is an asset accessible for everyone. Multiple companies can make use of the same data at the same time. However, the value of data depends on the context and data's format. (Parvinen et al., 2020.) Big data has become more and more vital aspect of companies' competitive advantage. In new business models noteworthy advantage sources are big data’s volume, pace, and type. (Sorescu, 2017.) Companies that aim to create value from their data assets may find that old business models are no longer suitable, instead, they must adopt data-based business models. In these data-based models’ companies monetize their data to create value. (Parvinen et al., 2020.) Data based business models have all one factor in common: data is used as a key character in value creation. (Fruhwirth et al., 2020.)

Business model as a concept has many different definitions. It can be defined as how the company creates value for its customers. Also, at some cases business model can be defined by the product design. (Sorescu, 2017.) Chesbrough and Rosenbloom (2002) define business model as the concept that combines technical aspects with the creation of economic value. A business model can be seen as an illustration or an architecture of firm’s value creation for customers. This includes describing the factors that create revenue and costs. (Teece, 2018.) Teece (2018) also mentions the importance of planning and the coherence of business strategy and business model. Moreover, Osterwalder and Pigneur (2010) insist that a business model describes the idea of how a company designs and captures value. Business model components can be divided into three main factors: value creation, value delivery and value allocation. Most business model definitions have this categorization of core factors in common. Value creation means the design of company’s services and products that create costs, revenue, and value. Value delivery focuses on the process and the surroundings of the marketplace for the product. Lastly, value allocation defines whether the costs outcome the revenue and whether the product or service provides financial value. (Sorescu, 2017.) These elements should be coherent with each other. If any major changes to business model for example technological transitions would come, all these factors should be considered before changes. (Teece, 2018.)

Business models take into consideration many angles and perspectives about business operations. Strategy and business model guide the organization’s operations and possible transformations. On the other hand, organizations with successful business models have usually clear intentions and plan for business operations. One business operation is to determine the core market segments. Particularly successful businesses have a scalable business plan that can be operated on multiple business segments. However, the initial business market and segment should be determined first. One other factor to consider is the differentiation from competitors. This can be differentiating business model to competitors, but it can also mean business innovation. (Teece, 2018.) Digitalization, technology, and data can work as a differentiating factor for businesses in the form of value creation. For example, with digitalization customer's needs can be met to and company's operations can be made more efficient. The urge to digitalization change does not always only come from the organization's intentions but also from customer's needs. (Rachinger et al., 2019.) Also, tools that enable effective use of data are in big favor. Cloud based products are a great example of an easily scalable technological solution for customers. Mainly, they are scalable because of their cost structure is profitable and the product can be easily duplicated. (Greenwood, 2010.)

Data businesses can be divided into three categories data users, data suppliers, and data facilitators. Data users utilize data either to their own internal usage or business purposes. Suppliers provide data to the others to use. Lastly, the facilitators offer platforms and consultation so that others can use and utilize the data efficiently. Also, when discussing data driven businesses we need to categorize if the business focuses on business to business (B2B) or business to customer (B2C) actions. When discussing about business models, the discussion is generally about the companies' utilizing data and providing a service to outside users. (Bulger et al., 2014.) Sorescu (2017) divides data-based business models into three categories depending on which data business they are. These business model categories are utilizing external data, utilizing internal data, and data insights. (Sorescu, 2017.)

2.4.2 Monetizing data

The most crucial step of creating data build business models is realizing how to create value out of data (Kühne & Böhmann, 2019). Bulger et al. (2014) also emphasizes the importance of data utilization and the chosen method to monetize data and create value. Data is attached to being a significant potential to business growth and positive factor to profit. Firstly, one way to monetize data is to sell it to the other users or third parties. Therefore, data can be seen as any other product. AIS data, such as the vessel's names, could be sold to third parties that monetize and analyze the data on their own. Also, the analyzed AIS data might have a significant value of its own. (Bulger et al., 2014.) Data can be also categorized into external and internal data to be sold to customers. External data meaning the data from outside the company for example producer data which can be analyzed and sent or sold to customers. On the other hand, internal data means the data that is generated inside the company for example customer data that can be then sold to customers back after analyzing it. (Sorescu, 2017.)

As such, another well-known business model is providing analyzing, consulting, advice, and other analytical services to customers about the data. This brings additional value to customers that might not have the resources for analyzing the data in the house. The possibilities with data analysis are diverse and innovative solutions create value and profit for the seller companies. The financial structure with data analysis is profitable since processing data becomes less and less expensive. (Bulger et al., 2014.) Company can create an advantage to others by utilizing data to create insights and combining data from other sources to create analyzes for customers. Analyzing and combining inside and outside data to create intelligent assist for customers works as another business opportunity. (Sorescu, 2017.)

Still in some of the companies comprehending the value of big data remains an issue. Then, one of the potential business models is consulting on the potential value of big data for the chosen fields and circumstances. (Bulger et al., 2014.) Various companies can accumulate data without knowing it. Also, they might not have the capabilities or the expertise to monetize the data. This can be turned into a business called data-based services that are aimed to assist companies to utilize the data they gather and solve business problems with the data. (Sorescu, 2017.) This type of consultancy can be divided into two categories technical and strategic advisory. Technical advisory focuses on the data structure and IT architecture for example data storage options and data management. Strategic advisory focuses on implementing data into business strategy so that data can help to enhance certain business factors. Advisory services about data applications and strategic usage of data are growing as a business area. (Bulger et al., 2014.)

2.5 Digital transformation in maritime

2.5.1 Data in maritime

Data from AIS is a great source for data analytics and AI maritime applications (Meyers, Azevedo & Luther, 2021). Maritime data can be categorized into two categories historical and real time data (U.S Committee on the Marine Transportation System, 2019). Maritime transportation is a great source of data since vessel’s track various elements on and off board and a significant portion of world commerce is conducted through shipping.

Vessels track and collect data about their own conditions, passing ships and internal technical factors. Maritime transportation could offer an opportunity for a further analysis of data if all the vessels would be willing to share their data. Also, not only vessel data for government and business purposes but also customer data need to be considered. Consumer data can be anything from luggage tags, boarding times, WI-FI uses to robotic bartenders and utilizing this data could be very informative. (Loredana & Iulian, 2017.)

Initially, AIS data is in the original high-density format, and it needs converting to be usable for analytical software. (U.S Committee on the Marine Transportation System, 2019.) According to IMO regulations AIS uses Differential Global Navigation Satellite System (DGNSS) service and RTCM standardized data formatting. Simply, RTCM is a standard format for GNSS data. RTCM formatting is initially based on GPS Navigational message structure. RTCM Documents for data formatting determine the message length, message type, word count and arrangement. Then, receiver creates the GNSS data which is then converted and modulated so that it can be sent to user equipment. (Heo etl al., 2009.)

The increasing interest in the maritime data and the usability of it in different other indented uses has created a need for a coherent and harmonized way to gather and analyze the data. This need urged International Hydrographic Organization (IHO) to create a data model standard S-100 for data usage. (Park & Park, 2015.) IHO distributes S1XX numbers for the S-100 applications. The numbers from 101 to 199 are reserved for IHO application specifications and the numbers higher than that are for other organizations. (IHO, 2022.) For example, the numbers from 201 to 299 are for International Association of Marine Aids to Navigation and Lighthouse Authorities' (IALA) application specifications and IALA is the corresponding organization for the S-200 product specification development (IALA, 2023).

S-100 standard can rather be seen as a framework for the development of maritime services based on data and the data exchange between stakeholders. One aim is for example to integrate more data into the navigation systems of vessels. IMO has adopted S-100 standard to e-navigation which means that all data must be in the specific S-100 format. This applies for example to meteorology data, image data, and AIS data. This standard aims to standardize data usage and product development now and in the future. (Park & Park, 2015.) To be able to develop S-100 applications the data must be interoperable. Since, the standard aims that the applications of S-100 are complementary with each other. S-100 framework has also specifications for the S-100 series applications defining for example the data encoding, data structure, and content for each application. Few application examples are S-101 Electronic navigating chart, S-102 bathymetric surface, and S-104 water level information for surface navigation. (IHO, 2022.)

2.5.2 Megatrends in maritime

Megatrends are scenarios of the changing future. Megatrends are typically portrayed with the help of five themes: nature, people, power, technology, and the economy. However, we must consider that all the themes relate to each other. The trends describe the changes in the environment with a broad perspective. Also, the trends aim to consider the long-term directions and long-term changes. (Dufva & Rekola, 2023.) Maritime transport is a massive sector since it handles around 80% of world trade (UNCTAD, 2018). In the past decades maritime industry has experienced massive change. In port areas the industry has developed from paper-based ports to ports considering integrated supply chains and lastly to smart ports that utilize data and Internet of Things (IoT) applications to improve and integrate services and networks around and outside port area. (Berns et al., 2017.)

Maritime sector has entered the next stage of digital evolution. In maritime transportation new technologies are tested and new technologies are implemented. After adoption of IoT technologies have urged other technologies such as edge computing and augmented reality to be tested in maritime context. The idea of augmented reality is to provide visualised data to the user by enhancing or recreating real life situations. (Plaza-Hernández et al., 2020.) In maritime logistics the concept of smart logistics includes new technologies such as blockchain technologies and smart contracts which should make maritime logistics even more efficient. (Phillip et al., 2019.) In the perspective of ports, the industry has developed to consider port and city collaboration and integration. Also, big trend is becoming integrating ports into the global supply chains and considering ports as a central concept in supply chains. Also, the term industry 4.0 has become familiar in the port and maritime industry concept (Zarzuelo et al., 2020). Industry 4.0 can be seen to be enabled from nine pillars of disruptive technology trends. These nine pillars are autonomous robots, simulation, horizontal and vertical system integration, IoT, cybersecurity, the cloud, additive manufacturing, augmented reality, and big data. These pillars form together a foundation for the industry 4.0. The aim of industry 4.0 is to integrate companies' and suppliers' individual data and product flows to the coherent value chain. (Rüßmann et al., 2015.) The concept of industry 4.0 in ports has been given a trendy name 'Port 4.0' standing for smart ports that exploit IoT, big data, and cloud computing. In various ports IoT is already utilized by gathering data from buoys, weather, other sensors, and stations and by using the data for planning and decision making. The Hamburg port can be used as an example of a smart port since it uses IoT in everyday operations. It for example uses machine learning and neural networks to assist with decision making around the terminal and cargo area by creating models and forecasts about the possible changes. (Zarzuelo et al., 2020).

In the recent decades technological development has been one of the biggest trends. Therefore, the future development of it only follows the current trend. However, we can say that the amount of data increases rapidly and AI and IoT keep developing. Therefore, one of the clear threats of digital disruption are the ownership of data and the dominance of technology giants. (Dufva & Rekola, 2023.) Therefore, in maritime cybersecurity and the trust for sharing information seem to be the main slowing factors in the digital transition. To release the full potential of IoT companies would have to share data more freely. Also, the digital transformation is happening at a different pace depending on the geographical location. European and Asian ports are ahead in the transformation compared to American ports. (Zarzuelo et al., 2020).

In the nature perspective future holds questions about how to revive the nature since we are in the middle of a sustainability crisis. Humans and businesses place major burden on nature that it can't carry. The nature needs ecological changes and the sooner the changes are made the better impact it will have. Nature's future and people's well well-being is intertwined with each other. For the people perspective the questions about working age population's endurance arise. Naturally, also big changes in sustainability, the pandemic, and uncertainty about financial situation and future brings a big burden to people's mental health. (Dufva & Rekola, 2023.) Ecological perspective is vital in the maritime environment because of the vessel's greenhouse gas emissions and energy usage quantities. In 2018 IMO established a strategy for cutting the emissions of vessels. The key short-term target is cutting emissions per shipping work 40% by 2030 when compared to year 2008. (IMO, 2011.) The work with regulating energy use and emissions continues. The newest addition to the work was the mandatory use of Carbon intensity indicator

(CII) certification that came into effect 1.1.2023. This measures carbon intensity and eventually allows to create framework for the carbon intensity rating. (IMO, 2022.)

Last megatrend perspective includes democracy that has experienced a big threat in the last few years because of Russia's invasion to Ukraine. This creates a pressure for all the democracies especially in Europe. Also, these events have created untrust in institutions. Furthermore, safety and feeling secure has become a major topic of conversation. The invasion has also affected the economic state of the world. Also, the economic crisis has created a need to reform economy since the economic situation is not sustainable. (Dufva & Rekola, 2023.) Also, in maritime sector organizations, companies and other parties have become quite aware of the security because of malicious cyber-attacks. Also, the new technologies that are under development have a high bit rate and are often integrated with multiple data interfaces and are therefore very attractive for attackers. New technologies must consider solutions for the protection of attacks. (Wimpenny et. al., 2018.)

3 Methodology

The methodology chapter clarifies and describes the research strategy and process of this thesis. After discussing research strategy data collection and data analysis methods will be presented, discussed, and explained. Lastly, this chapter will discuss the quality, trustworthiness, and ethics of this research.

3.1 Research strategy

Planning of a research strategy and process is as important as defining the topic of a research. The research process planning includes a schedule, theoretical framework and decisions of data collection method and analysis method. After selecting themes and the topic of the research researcher can move on to defining the research questions. Then, research questions guide the selection of a suitable research method. After that, data collection method and the plan for analysis method should be constructed. These depend on the types of data chosen for the research process. (Eriksson & Kovalainen, 2008.)

This research is conducted as a qualitative case study research to explore AIS as an evolving phenomenon in maritime industry. One of the main aspects of qualitative research is to create detailed new information about a certain phenomenon (Puusa et al., 2020, p. 5). Qualitative research aims to study a specific phenomenon and generally answers questions like how, what, and why (White & Cooper, 2022, p. 234). Qualitative research differs from quantitative because it aims to describe and explain the phenomenon with other techniques than statistical and quantification. (Fossey et al., 2002. p. 717.) Qualitative and quantitative research can be often seen as opposites to each other. Usually, the data collection strategies differ between these two. The data for quantitative research is usually numerical and for qualitative the data is usually in the form of a text. (Puusa et al., 2020.)

The research methodology of this thesis is a case study. Case study is a method for analysing a specific problem or phenomenon. Case research methodology is widely used in qualitative research. The methodology was widely accepted as the research in medicine, social research and political sciences were successful. Case research aims to find upcoming trends, clarify key issues, and provide wider understanding of a certain phenomenon. Plainly, case research studies a phenomenon in a real-life context. There are multiple ways to gather data and gain knowledge about a phenomenon. These data collection options are for example interviews, documents, reports, quantitative data, and observation. Case study is adaptive and flexible way of research which allows new issues to arise. (White & Cooper, 2022, p. 234-235.)

In this thesis the research process started from framing and specifying the research subject. After selecting and setting the limits for the topic the research questions were conducted. Next, the theory and literature review were created to gain more knowledge for the interview questions. The literature review answered the first research question. The data collection method was decided early on simultaneously with conducting literature review. However, the data analysis method was decided later when the literature review was almost ready as the researcher read similar researchers about the topic and gained knowledge about possible data analysis methods. Subsequently, after the method choices and literature review the data collection and analysis was conducted. The more accurate descriptions of data collection and data analysis are described later.

3.2 Gathering of empirical materials

3.2.1 Choosing of interviewees

When gathering empirical material, the quantity of the interviews is not the key point. More important is choosing discretionarily small group of interviewees and emphasizing the quality of the interviews. The interviewees can be for example specialists or consultants of the subject. Usually, it is said that there should be as many interviewees as needed for the research. The quantity does not matter as much as quality of the interviews. (Puusa et al., 2020.) Therefore, purposeful sampling is frequently used method for gathering interviews and data for qualitative research. The aim of purposeful sampling is to gather interviewees that are experts and know a lot about the phenomenon. (Patton, 2002.)

In this research the researcher chose to interview five companies and their representatives. Purposeful sampling was used to choose the companies and companies that were contacted were chosen carefully for the purpose. The chosen companies are described below in the table 8. All five of the chosen companies were maritime field focused. Three of these companies were data users, the fourth one was focusing more on providing the data and the last one was technical solutions provider and VDES developer. Therefore, the aim of the case study was to gather different views and perspectives from maritime field. Also, it was important that these companies had the capabilities and resources to innovate future uses for AIS data. AIS data and its usage in their business activity is one common denominator for choosing these companies specifically. The emphasize in choosing these interviewee companies was in the AIS data usage and different current uses of AIS within the company. Also, companies with any ongoing projects for AIS in the future was seen to bring broad perspective to the study. The chosen representatives from the companies were technology specialists and area managers. These representatives were identified as key persons for interviews because they held the best knowledge about ongoing AIS projects and technical information about AIS data uses in the companies. The selection of the companies and representatives was optimal for the research. New views arose during the interviews, but the interviews also supported each other in the context of the research problem. The summary of the interviews can be seen in the table 7.

3.2.2 Semi structured interview

The chosen data collection method for this thesis is semi structured interview, which is commonly used in qualitative research (Fossey et al., 2002. p. 726). Qualitative research interviews can be divided into three categories structured, semi-structured and unstructured interviews. For qualitative research semi structured interviews are the most common interviewing technique. (DiCicco-Bloom & Crabtree, 2006, p. 314-315.)

Semi structured interviews aim to find more diverse answers and therefore use interview questions as a foundation for the interview. Semi structured interviews usually have interview questions that aim to guide the otherwise casual conversation. In semi structured interviews the researcher and the participants can depart from the question structure if any underlying ideas have emerged, and the conversation flows in the right direction. (Fossey et al., 2002. p. 727.)

Before conducting the interviews and building the interview structure, interviewers should conduct preliminary research to gather relevant information. The preliminary research is essential for creating the interview questions and structuring the interview effectively. The interview structure is built before the interviews to act as a frame and guidance for the discussion. Since the nature of the interview is open, the interviews should be recorded so that researcher can later check the transcripts. (RWJF, 2008.) In this research, all the five interviews were transcribed to help the upcoming analysis process. The research questions should also be open-ended so that interviewee can answer more than just yes or no to the question. Therefore, the research questions should be designed to answer questions how, why, and what. The structure of the questions should be designed so that the interview starts with introduction and easy questions and then moves on to more difficult ones. (Jacob & Furgerson, 2012. p.3-4.)

In this thesis the interview structure had 11 questions including introduction question. However, the structure of these questions was changed according to the conversation. Also, new specifying questions were asked during the discussion. The first question was about the background of the interviewee and their work. Then the discussion moved on to general questions about the topic and lastly the discussion moved on to more specific and more difficult questions about AIS system. In this interview, PESTE framework was used as a background theory for the interview structure. The interview structure can be seen in appendix 1. The interviews lasted about 25 to 60 minutes. Semi structured interviews can be conducted as either individual or group interviews. (DiCicco-Bloom & Crabtree, 2006, p. 314-315.) In this thesis most of the interviews were individual interviews but one was held so that there were two interviewees (P2) The list of interviews, their duration and the title of the interviewee can be seen in the table 7 below.

Table 7 Interviews

Code	Company	Title	Interview duration
P1	Company A	Lead data scientist	25 minutes
P2	Company B	District manager and technology manager	59 minutes
P3	Company C	Programme manager	45 minutes
P4	Company D	Vice president, site manager	32 minutes
P5	Company E	Head of strategy	51 minutes

Table 8 Descriptions of interviewed companies

Anonymized company name	Description of the chosen company
Company A	Global leader in smart technologies and solutions in the marine and energy sector.
Company B	Finnish state owned pilotage company.
Company C	Company that controls traffic on land, at sea and in the air.
Company D	Company works at the marine industry. It provides innovative solutions for merchant marine, navy, coastal marine and others.
Company E	Originally Swedish company providing airborne AIS transponders.

3.2.3 Data collection

Four of the interviews were conducted in Finnish since it is the native language of the researcher and the interviewees of those four companies. However, one interview was conducted in English as the interviewee did not speak Finnish. This was held in English because it was the most fluent common language for both the researcher and interviewee. By using the native language or the most fluent language, we could ensure the diverse answers and avoid distortion. Researcher should aim to conduct the interview in a neutral but accurate way to avoid misunderstandings. Therefore, the decision about the interview language is critical. Right decision about the language can potentially ease the experience for the interviewee and help the researcher to discover authentic and more accurate responses. (Welch & Piekkari, 2006.)

The interviews were structured by using industry analysis technique PESTE as a foundation for the questions. PESTE is widely used in the concept of future research. PESTE technique is supposed to help to consider multiple factors in the research environment. Especially, when researching future scenarios, it is important to consider multiple factors and how they affect the research object. Without the PESTE framework some of the outside factors might be missed so the technique enables the researcher to consider and identify underlying phenomenon. PESTE consists of five key factors political, economic, social, technological, and environmental. (Dufva, 2022.) When studying a phenomenon qualitative research aims to also research the environment and the factors behind the phenomenon (Puusa et al., 2020, p. 26). The five factors acted as a foundation for the research questions to help the researcher find any underlying phenomenon when discussing the scenario of AIS usages in five years from now. With the help of PESTE framework, the research area was studied further regarding the restrictions of the maritime environment and to arouse underlying possibilities of AIS usages. To add, the framework with the support of 'Megatrends in maritime' literature subchapter created basis of the categorization for the analysis of empirical data. Lastly, the interview ended with returning to the first question to discuss if there were any underlying phenomenon that interviewees identified during the interview and to discuss further the possible uses of future AIS data.

Interviewees had the opportunity to ask further questions and ask to clarify any of the research questions. Interviews were mostly individual but one of the interviews had two interviewees. Group interviews usually offer the researcher a wider scope of experience (DiCicco-Bloom & Crabtree, 2006, p. 316). The interview worked well since the other person was district manager and the other one technology manager and together, they complemented each other's expertise. All the interviews were recorded, and the recording started from the first question. All the data was anonymized to protect interviewees and their companies' privacy.

3.3 Analysis implementation

The purpose of a data analysis is to process and interpret data to illustrate and describe the phenomena (Fossey et al., 2002. p. 728). Illustrating is important and presenting the analysis and facts in a real-life context for the reader. The aim is to create a coherent and rich picture of the facts, research phenomena and overall present well-argued conclusions of the matter. (Puusa et al., 2020.)

In this research the used analysis technique was content analysis, which is the most used analysis technique. The technique can be seen as a framework for the categorization and analysis rather than a strict method. Content analysis usually starts with reading the interview scripts repeatedly to gather information about what kind of categories and themes arise from the material. It is recommended to start with categorizing the material and then dividing them into themes. Lastly, the important factor is to draw conclusions of small details into a bigger picture. The analysis process starts with reducing the original expressions into simple expressions. Then, the process continues into categorization of these expressions. This is called coding on the material. Coding means that similar expressions or expressions with identical words are identified. After this, the expressions are grouped together according to themes. Lastly, similar categories are combined to construct parent categories. (Puusa et al., 2020.)

Typically, there are two approaches to the analysis. A theory-bound thinking and material-oriented perspective. In theory-bound thinking themes or sections are picked for examination based on the theory and literature review. The direction for the analysis is guided by the theoretical framework and in the theory-bound thinking process is influenced by the material orientation and previous theoretical knowledge. In the material-oriented perspective theory is partly excluded from the thinking process and focus stays on the material and any themes and categories rising from the material. (Puusa et al., 2020.) In this research theory-bound thinking was used for the analysis since the theory supports the empirical material and many themes in the theory have arisen in the empirical material. PESTE and megatrends are combined and used as a categorization for answering research question about potential uses and applications of AIS. The PESTE framework in itself is not used as a categorization for analysis. These final categories are security, ecology, technology, and financial focused usages as in the picture 10 below. The subcategorization of different types of data applications originates from the subchapter of monetizing data. Monetizing data subchapter studies different types of data applications and monetizing data in the context of data-based business models. These categories are data as a product, analysed data, and data-based services. As part of content analysis, not all subcategories arose new usages from the interviews and therefore all three monetizing subcategories are not used in the four main categories as we can see in the image below. The specific definition on the subcategories is presented in the subchapter monetizing data. The categorization of interview data of this research is presented in the figure 10 below.

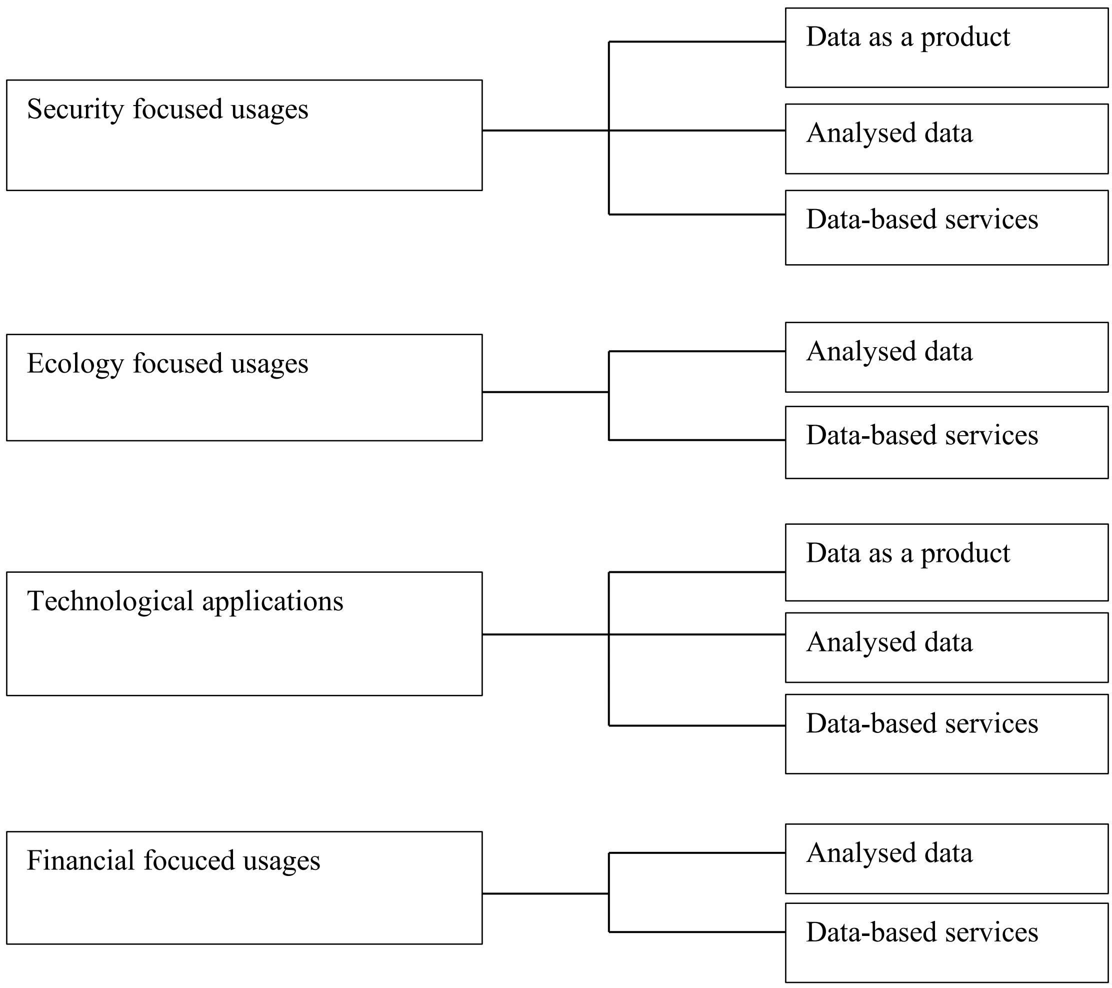

Figure 10 Categorization of interview data

After categorization of future usages of AIS, the analysis of technical characteristics of AIS was conducted in a form of a table. The technical problems that arose in the interviews about AIS were listed and grouped together if they were said multiple times. Then, researcher checked if the new added features of future VDES aim to fix these problems. Then, researcher checked if the problem was aimed to be fixed with new characteristics of VDES. The analysis table of interview data about technical problems of AIS is presented in the table 9 below.

Table 9 Analysis of technical AIS problems interview data

Current problems in AIS	VDES aims to solve
No accurate enough position data when docking	
Manually entered data unreliable	
ROT data not automatically available	
Cybersecurity problems	x
Update rate of position data	
Radio coverage problem	x
Only one antenna	
Radio range limitations	x
Limited number of slots	x
Small data packages	x
Data format heavy for calculations	
Switching from satellite to coastal antenna	x
Open sourcing of data not available	
Narrow radio band	x
No authentication	x

After the coding process comes the interpretation and conclusions stage. Conclusions are created with the help of syntheses which are drawn from summaries and analyses. It is central that researcher can present derived and well-argued conclusions. The conclusions are then compared to the theoretical framework and previous knowledge. Researcher's ability to present logical arguments to support the conclusions made is vital for the conclusion process. (Puusa et al., 2020.)

3.4 Quality of the research

The core objective of the research is to gain as much knowledge about the research phenomena as possible. Therefore, the main factors of quality evaluation are the interaction of researcher, participants, and material as part of the research process. When considering research quality, compatibility of analysis method gathered theory and gathered material is evaluated. (Puusa et al., 2020.) However, the quality of the research depends on various factors. Reliability and validity are frequently used categories to evaluate quality and they measure the research sample size and the data collection measures. Naturally, also authenticity of the presented material and interviewees perspectives affect the quality of the research. Also, when evaluating quality of a research good research practice and trustworthiness of the results are key concepts to consider. Generally, the quality of a research practice and trustworthiness can be evaluated through five categories. (Fossey et al., 2002. p. 723-725.) However, there are different categories to evaluate research quality. Example of these differences are presented below.

When measuring research practice through Fossey et al. (2002) categorization congruence, social context, suitability, adequacy, and transparency are the key criteria for the evaluation. Congruence category measures the chosen methods, methodology, and research practise. Ultimately, this measures the methodology and if it was consistent throughout the whole research. The other categories suitability and adequacy measure the data collection methods and analysis. Eventually, evaluating whether the data collection and analysis methods were suitable for the research questions. Lastly, transparency category evaluates data collection and focuses to evaluate the analysis processes. For example, how was the analysis conducted and if all the aspects of results were included in the research. When analysing trustworthiness, Fossey et al. (2002) criteria for that are authenticity, coherence, reciprocity, typicality, and permeability. First categories authenticity and coherence evaluate the findings and how did the data link to the results. This category includes presenting interviewees voices in the research for example by presenting quotes from the interviews to show the links from the data to the results in practice. Reciprocity category means the amount of involvement of the interviewees in the research process. Typicality measures whether the research could be generalized to other contexts. Permeability measures the researcher’s role, intentions, and previous knowledge in the research process. (Fossey et al., 2002. p. 723-725.)

In comparison, Eriksson & kovalainen (2008) common categorization of criteria for trustworthiness of qualitative research is credibility, transferability, dependability, and confirmability. Credibility measures the links between the material and categories. Credibility essentially evaluates the results and claims of the research and whether they have clear links to material. Transferability assesses whether similar conclusions and results could be found in other contexts and research. Dependability is evaluated by assessing the research process and has it proceeded logically and is it well documented. Lastly, conformability category stands for the idea that results and research should be able to link to real life situations so that it is easy to understand by others. (Eriksson & Kovalainen, 2008.)

In this thesis the credibility and dependability criteria were considered by describing and explaining the research process, data collection decisions and the method choices throughout the process. The categorization of the results is also seen arising from the interviews when conducting content analysis. Also, in the collection of data different views were represented since the companies were chosen from different fields some being the data providers and some being the data users. Interviewees voices and views were presented as their own and this was supported by using quotes from the interviews in the research to support the link between analysis and data. Regarding transferability category the research was conducted by focusing on the Nordic countries. Still, the research case could be placed somewhere else in the world and similar results would most likely appear according to the previous research and literature review. Also, when considering the results of the research they display the megatrends of today's world and therefore similar results could be seen in also other fields. Critically thinking the case study was conducted in a specific sector and possibly therefore individual findings cannot be duplicated for all other sectors. However, Conformability can be seen relatively easily since the research is conducted as case research so real-life examples are provided throughout the research.

Permeability was considered so that researcher aimed to the most objective research approach and tried to keep objective distance to the subject to keep a clear visual of the research problem. Also, the results were drawn from data and not from researcher's assumptions because researcher acknowledged their previous knowledge about the subject. Lastly, the researcher considered the results and conclusions of the research critically and with caution.

3.5 Ethical aspects

When evaluating the quality of a research the ethics of a research are always considered central part of the evaluation. Ethical evaluation usually focuses on the encounter of researchers and interviewees. Therefore, the focus of an ethical research is on the trust between researcher and the subject of research. The trust can be gained through ethical acts, complying with regulations, and offering respect for each other during the research process. (Puusa et al., 2020.)

The most pressing aspect of interview data is the data protection regulation which must be considered when dealing with interview data. Also, anonymization of the interviewees must be ensured. In addition, it is extremely vital to verify that participating in the research is voluntary. (Puusa et al., 2020.) Participants should not have an assumption that they are required to participate in the research. In addition, participants must be informed that they can withdraw from the process at any point. (Eriksson & Kovalainen, 2008.) Also, when interviewing companies and representatives, there must always be permission for recording of the interviews. Permission must be always verified before each interview and clarified before pressing record button. Moreover, the storage and the storage period of the recordings and possible data must be informed. Possible further usage of the data must be separately arranged. Lastly, according to good ethical manners, the researcher should provide enough information about the aim of the research and research practices. (Puusa et al., 2020.)

In this research the ethics were considered and ensured by the researcher. The researcher performed the literature research, data collection, and interviews in a critical and careful way. The literature was combined from several different references considering multiple different angles of the topic. The literature research was conducted in a professional manner. When collecting data, the interviewees were informed about the process being anonymous and the data was anonymised for the research process. The interviewees were informed about what was the research purpose of the gathered material. The trust between the researcher and interviewees was maintained throughout the whole interview process. To add, the interviewees were informed about the process being voluntary and they could retreat at any point. Before each interview a permission to record was asked. Lastly, the interviewees were offered an opportunity to read the finished research.

4 Results

This chapter discusses and presents the results from the case study. The results are presented and divided into five subchapters based on the categorization of interview data and one subchapter for the analysis of AIS technical problems and comparing them to the future improvements on VDES. The technical characteristics of VDES are presented in the literature review.

4.1 Security focused usages

Security focused usages appeared in all the interviews. The security and safety aspect were expected to arise in the interviews since initially AIS was invented to increase maritime security. One of the interviewees highlighted the basic idea of AIS location data in a following way:

> *"... it also creates a general picture of the situation, which is shared with other authorities as basic information about what is going on in that sea area." (Company C)*

Also, discussion about aspects that initiate to update and develop AIS circled around two themes: security and financial initiatives. Standardization of certain AIS features or updates also leaned to improvements in maritime security. The security focused usages considering data as a product included two-way communication and port to port communication which are meant to increase the security due to fluent communication and dataflow between partners of matter. One interviewee commented about the two-way communication in the following way:

> *"...there is potential for it to be used much more widely for communication, because in the end AIS is radio communication and potential lies in not only in the one-way but also two-way communication between different parties..."(Company D)*

Other usages considering analysed data included new analytics about the current surrounding situation and intelligent modelling about possible deviations. Again, improvements on situational awareness were a key factor when discussing new possible usages for AIS data. So analysed data and support for the vessels control bridge were considered important for the future usages of AIS. AI and analysing tools could be also used to detect any illegal activities and black vessels. Data could be analysed with the help of AI to detect anomalies and locate black vessels. In this context black vessels or dark vessels refer to vessels that have switched their AIS off. With the help of AI any illegal activities could be spotted more efficiently.

Data-based services that arose in the interviews included filtering option for the AIS screen to filter small vessels away and automatic collision avoidance tool. One interviewee emphasized that in most of the cases the bigger vessels are more important to see on the map and huge amount of small vessel data can disturb the map view. Therefore, filtering option felt necessary. Another interviewee shared this view and presented an example of a situation where suddenly couple hundred of smaller vessels appear on the map at a critical timing. On the other hand, other interviewee commented that smaller vessel data can be very valuable for example for emissions analytics and data quality. Therefore, B class transceivers should be made mandatory for smaller vessels. Automatic collision avoidance tool was one other data-based service to have arisen from the interviews. One interviewee suggested even combining the filtering tool and automatic collision avoidance tool so that the analytics would know what vessels they need to avoid. Automatic collision tool still needs quicker rate of position data so that automation can be conducted about the data but as a future usage it can improve vessel's safety and overall maritime security.

4.2 Ecology focused usages

Ecology focused questions created a wishful atmosphere and some interviewees seemed even positively surprised about talking about this topic. This could be also due to the shift in the conversation from the political view to the more lightweight ecological aspect. One interviewee commented the ecology aspect following way:

> *"The environmental point of view is indeed interesting, haven't thought about that at all." (Company B)*

The discussion of ecology is fairly new in the field but upcoming changes in the field created good conversation. Overall, the discussion about the ecological aspect and usages of AIS was very fruitful and the interviews complemented each other on this aspect. All the interviews had one suggestion in common: as a data-based service AIS data can be used to green monitoring of ships more specifically for emission monitoring. As one of the interviewees discuss, IMO has a great emphasis in the development of ecology focused metrics.

> *"Well, now there are certain regulations of the IMO International Maritime Organization, about how much emissions ships can produce." (Company A)*

After IMO establishing regulations for the emissions of vessels new analytics have been invented to calculate vessel's emissions. Further analytics and calculations about emissions and monitoring have a place in the field.

Then, ecology focused usages about analyzed data included green ranking of ships meaning that ecological supply chain could be made more transparent for the transport services and big companies. Green monitoring of vessels could work as a base for the green ranking. After making the ecological impacts of vessels more transparent companies focusing on the importance of green supply chain could choose the vessel's that pass their ecological preferences. One other ecology focused usage for analyzed data is to detect pollution ejections. The navigation data and outside data could be analyzed with the help of AI. With the help of these locations of emission ejections could be spotted. Also, even emission maps could be created with the help of AI. Eventually, this can be used to help endangered species by protecting specific areas.

Lastly, we should mention also fuel saving analytics and fuel optimization under ecology focused usages even though they will be discussed later in the financial focused usages more thoroughly. One interviewee commented the fuel optimization in a following way:

> *"Yes, of course, if we are able to make better use of it in this just-in-time operation, i.e. if we can optimize the time at the port, it is certain that when you safe fuel, it is immediately visible on the environmental side as well." (Company B)*

Another interviewee also mentioned that ecological benefits might come along with enhanced efficiency:

> *"...we're calculating the reduced fuel consumption, if the ship is going the proper way. Not just going the proper route, but also, just in time in the harbour." (Company E)*

Overall, all the companies agreed that AIS till today has mainly focused on the security and safety aspect but next generation AIS, and the new usages could be very potentially ecology focused.

4.3 Technology focused usages

Technology focused usages include innovations focusing on the development of AIS technology. Usages of data as a product include higher quality data utilization which is quite general statement. The interviewee compared maritime to aviation industry where data is precisely correct or otherwise it is a violation of protocols. In that case, in aviation data is more precise and data quality is higher. Therefore, maritime industry should try to aim for the same situation so that data could be utilized more efficiently and for multiple different purposes after ensuring the higher data quality. Other future usages that arose in the interviews were predictive navigation design and other predictive applications to help support the operational planning on board. One interviewee commented about future usages in a following way:

> *"That's the direction it's going, to support the navigation of a ship, to support proactive planning, route planning…" (Company B)*

Data-based services included routing services, self-guided ships and S100 and S200 standard products. The big long-term vision of the future AIS usages is self-guided ships. This requires very exact and precise information about the location data and AIS plays a big role in this. For now, AIS update rate of position data and quality of data were a matter of discussion when playing with the idea of self-guided ships. Then, IHO's and IALA's have provided S100 and S200 standards that could be turned into product suggestions. One interviewee excitedly explained new technology driven opportunities as follows:

> *"With VDES we can utilize these S-100 and S-200 standards, so we can get to a point that IALA and IHO's standards can be put to use, and it will be possible to start using different technical services, i.e. to offer routing services." (Company C)*

These S-100 and S-200 standards present different types of new application options for future of smart maritime. These standards are for example presenting information about water level, port services or radio arrangements. Just to list few other S100 standard products for example marine information on harbour infrastructure, navigational warnings, and information on surface currents. The S-200 products are for example application specific messages and port call message format. (IHO, 2022.) These standards offer ideas for future developments of maritime focused products and data usages.

4.4 Financial focused usages

When asked about financial aspect, interviewees discussed maritime field as a budged focused field. Financial situation and financial motivation work as an incentive in the development of technologies in maritime field. Therefore, when innovating and developing technologies, money and financial situation can also work as an obstacle. One interviewee commented about the financial situation of maritime field as follows:

> *"Nothing else but the fact that shipping should change from a budget sector to a field of transport that should be seriously considered and invested financially in." (Company B)*

Analyzed data usages include opportunities for fuel optimization and analytics and therefore major cost reductions for vessels. As briefly mentioned, fuel optimization is also included in the in the subchapter of ecology focused usages. Since, fuel savings and optimization naturally improve the environmental effects of maritime. Data-based applications also work to safe costs for example just in time applications share the financial perspective so that by optimizing the waiting time around port area, vessel could make significant cost savings. Then, virtual arrival applications calculate the docking time and reduce speed to meet with the given arrival time to dock. Overall, port optimization tools and just in time applications were mentioned by several of the interviewees. They felt necessary for the future to optimize the port operations so that the vessels don't stand around the port area waiting for an approval for docking and therefore waste fuel.

Also, other usages like automatic docking and remote piloting can make savings in wage costs in the future. Again, the discussion about remote pilotage and automatic docking arose the question about how to get investors interested in the innovation of these future usages so that the development could begin. Discussion was filled with frustration and questions like the following:

> *"These applications, which require great precision, so how can these be sold to the outfitter? Or to the umbrella organization? Because outfitters tell those flag states what they want and where they are willing to invest in." (Company B)*

Automatic docking and remote pilotage remained a subject of conversation throughout the interviews and remote pilotage was seen as a real-life goal within the next five years and AIS data was seen as a vital part of the process of developing this application and managing the maritime traffic.

Lastly, one aspect to mention when discussing the financial aspect is the uprising costs of the technology devices. While technology develops and new financial driven usages emerge, also the costs for each vessel rise. One interviewee described this in a following way:

> *"Economically, VDES box gonna cost roughly 40 to 50 percent more than an AIS box." (Company E)*

Also, when asked about the financial burden for smaller vessels, the interviewee continued:

> *"Yes, of course, maybe that can be a burden, especially for inland or national vessels, small SOLAS vessels." (Company E)*

When discussing financial focused usages, one must also consider the financial effects of the possible new usages for the end users. Because, that might effect whether the end user will actually implement the technology or not.

4.5 Technical aspects about future of AIS

This subchapter describes the technical problems of current AIS and compares them to the future of VDES technology and new features that are planned. As seen in the table 9. AIS technology will not change but new features will be added when introducing VDES. Therefore, some problems in the current AIS can be fixed with the initial new features of VDES. The first problem occurred was the quality of the data when docking. The data is not trustworthy enough for the future developments of automatic docking and self-guided ships. The concept of data quality is also affected by the update rate of position data. In the concept of AIS in VDES there are no updates to AIS technology and therefore we can say that the new features of VDES do not aim to correct this problem fully.

The next problem arose in the interviews was the manually entered unreliable data. One interviewee discussed the problem that in many cases the personnel does not care to update the manually inserted information. Also, personnel might not care to check the transmitter's position and alignment. This problem of manually inserted data is also discussed in the literature review and widely studied in the research in the field. In the literature generally two categories of threats for AIS can be identified, the implementation level and the other is protocol specification level (Balduzzi et al., 2014). As said earlier, AIS itself does not change and new features don't fix this problem of manually inserted incorrect data. One interviewee had few solutions for this and commented the problem in a following way:

> *"If the current legislation already obliges international legislation to do certain things and we still don't get people to do so, then I don't know. Increasing control? Sanctioning?" (Company B)*

Next current problem is the ROT data availability. ROT data is not automatically available, and this problem was also discussed in the literature section. ROT needs an outside indicator that needs to be connected and therefore the data is not always reliable and available (Rong et al., 2022). The next current problems of cybersecurity are aimed to be fixed with the new features of VDES. To be specific, authentication of AIS messages will become available since VDES provides more bandwidth and therefore authentication messages can be sent. However, update rate of AIS data is not changed since the current technology is not changed and therefore the update rates will remain same.

The next problem of discussion is the update rate of position data. This was discussed earlier but to conclude new features of VDES will not improve the update rate of position data. This affects the data quality and serves as a problem around coastal areas. One interviewee commented that the data should update in a real time and at least every second. One interviewee commented this problem in a following way:

> *"Similarly, the location information depends on the mode chosen, it can be so that the update rete is around four to five minutes, which is completely irrelevant at that point." (Company B)*

Another interviewee concluded that this current update rate of position data acts as the main brake for future AIS usages:

> *"So, you would need this high-frequency data even faster…. This kind of high-frequency capability, makes such sophisticated thigs possible, like self-steering ships in ports, automatic dogging i.e." (Company A)*

However, VDES as designed does not improve update rate but provides an opportunity for further development of faster update rate because of the improved bandwidth that supports frequently sent messages.

Next, issue identified was about radio coverage problem since it changes in different ports and areas. This is relating to the problem of switching from satellite to coastal antenna.

This means that in some areas at sea the coverage is weaker and especially when the receiver switches from satellites to ground stations or vice versa. There can be a weaker point when the exchange of satellites to ground stations happen and therefore the coverage is weaker. As presented in the literature review one of the biggest improvements of VDES is the use of ACM for transmissions. As stated, the system chooses the best modulation and coding for the current situation. Therefore, we can see clear improvements on the position data coverage. This will also aim to fix the radio range limitations because of the ACM ability to check the best modulation and coding for the data transmission. Also, switching from satellite to coastal antenna should become more efficient because of the ACM.

Another problem of AIS is that it only has one antenna. This was seen as a problem because of any technical problems for example the transmitter shutting down. Antenna could work as a backup and with another antenna shutting down or other technical problems of the antenna would not be an issue. Also, the other data transmitter could be used to check the data and, in a way, verify the position data. For now, AIS uses only one antenna and there is no plan to add other antennas. However, VDES provides an opportunity to use multiple antennas in the future (Lázaro et al., 2019). Considering the equipment of AIS, on problem seen was the fact that the equipment must be on board and implemented on board. Meaning that the equipment is not ready installed on the vessel. Since AIS equipment will not change after implementing VDES, therefore this detected issue will not be fixed with VDES. To argue, this specific problem will be even emphasized more when VDES transponders are implemented on board. This implementation process can take long time to complete for all the vessels of matter. One of the interviewees mentioned a problem that another ship cannot know if the other ship has VDES box yet or not. Therefore, messages on VDES channels might not go through. This implementation period is therefore creating a difficult situation for the vessels.

Limited number of slots and small data packages were mentioned often in the interviews to be vital issues. One interviewee commented this problem in a following way and emphasized the issue affecting the data content:

> *"It is probably the amount of data that can be sent via AIS. It is perhaps the biggest limitation at the moment, because we are talking about very small data packages." (Company D)*

VDES aims provide new communication channels and therefore number of slots will increase. In this way, VDES allows bigger data packages to be sent. Also, narrow radio band was mentioned as a definite issue when talking about AIS. As VDES offers new channels to VHF band it aims to solve this current problem of narrow radio band. One interviewee commented that the data format of AIS is very heavy for calculations. Initially VDES will not aim to have changes to data formatting and therefore this is not to be fixed. Also, problem with the open sharing of AIS data was mentioned in the interviews but VDES will not aim to fix this. The problem of open sharing is not only a technical matter.

5 Discussion and conclusions

This chapter starts with discussion and then moves onto conclusions and limitations of the research. The discussion combines the results and theoretical research, and conclusions present the findings of the research. Lastly, the research limitations and discussion about further research and the contribution to maritime field research is presented at the end of the chapter.

5.1 Discussion

The purpose of this thesis was to study the current uses of AIS data and its current best practices, challenges, and technical limitations. The aim of this thesis was also to discuss the upcoming developments and modifications of AIS. In this research IS success model was used to create framework for answering the research questions about the usages of AIS data and its technical limitations. This research provided valuable insights into the future usages of AIS in the maritime field. The findings of this research highlighted the importance of security, ecology, technology, and financial considerations in shaping the future developments of AIS.

The findings regarding the new uses of AIS data corroborate with the previous research. For instance, Zarzuelo et al. (2020) highlights the potential of port optimization, while Wright et al. (2019) mentions ecological assessment applications and other analytical tools for example route optimization. The interview results align with the proposed future uses of AIS data. It is worth noting that one aspect emphasized in the previous research, namely the optimization of the cargo supply chain, was not explicitly mentioned in the interviews. However, the subject was touched in the discussion of fuel savings. This can be attributed to the fact that the interviewees were not ship owners. Nevertheless, the overall findings remain consistent with the existing research and this study's exploration of new, innovative applications to the maritime field. Regarding VDES, this research has conducted technical analysis and summarized the key issues of AIS raised in the interviews, aligning with AIS related research on its limitations. By combining these findings this study provides an additional comprehensive understanding of the current state of AIS technology.

The IS success model guided the research framework and the study started with investigating the technical limitations of AIS and measuring the quality of AIS data. One of the key issues that emerged both in the interviews and in previous research was the resilience on manually entered data. manual data entry poses a risk of human error, especially when implementing AIS and inserting core information. (Harati-Mokhtari et al., 2007.) Then, the study of data quality and technical limitations continued to assess of three aspects: AIS message range, message slots and cybersecurity of AIS. These aspects also arose in the interviews as main technical issues of current AIS. These were then compared to the improvements of VDES, and it appears that these aspects will be addressed and improved with the introduction of new features. The IS success model also suggested to study current usages and also evaluating whether the existing technical aspects meet the future potential uses. It became evident that the current technical characteristics of AIS have reached their limits and become outdated. Therefore, the introduction of new technical advancements, such as VDES, are highly anticipated in the field and also enable further developments and applications on the field.

By evaluating the technical aspects and the usage satisfaction, the IS success model enables an assessment of the overall net benefits. In this study, the assembly of individual results implicate the evaluation of the overall net benefits of AIS in the maritime field. Overall, AIS technology has proven to be advantageous for the maritime industry, as it has brought forth new applications and helped to identify the need for further applications. AIS also offers an opportunity for further developments and exploration futuristic scenarios. Moreover, AIS limitations are well recognized within the maritime sector, prompting the industry to test and innovate new developments such as VDES as potential solution. As Plaza-Hernández et al. (2020) emphasizes that maritime field has entered the next stage of digital evolution considering technologies such as IoT, augmented reality and edge computing. Therefore, we can say that the maritime sector is awaiting the advent of new technological improvements also considering AIS. When considering the net benefits of AIS, it becomes apparent that they are multidimensional. AIS offers advantages in terms of safety, operational efficiency, and potential future growth. These benefits extend beyond immediate gains and have potential to positively impact various stakeholders within the maritime sector.

The results suggest that the new VDES implementation will be time-consuming process, spanning several years. Overall, VDES is seen as an additional feature that has potential to address the technical challenges associated with AIS. Moreover, VDES opens up possibilities for future advancements in AIS data usages, such as developments of self-driving vessels and remote pilotage. Results also imply that AIS data holds great potential for various different business purposes in maritime sector. Additionally, incorporating other relevant data sources for example data from databases, weather data and satellite imagery can enhance the utilization of AIS data and create ideas for further AIS data usages. Financial, legislative, and safety factors collectively drive the utilization of AIS data, enabling businesses to optimize operations, ensure compliance and enhance safety standards.

5.2 Conclusions

The analysis process should be taken as far as needed to gain meta-level observations and conclusions (Puusa et al., 2020). This research aimed to study the AIS data usages and technical limitations. The first research question of this thesis was “What are the current uses and applications, best practices, and challenges of AIS? “. The second research question of this thesis was “What are the future potential uses/applications of AIS, and how AIS data format and configurations will impact future services?”. The empirical material of this thesis was collected with semi structured interviews.

The results are presented in five subchapters each based on the categories derived from the interview data. Additionally, a separate subchapter was dedicated to focusing on the technical aspects of AIS. The results indicated that the security-focused usages emerged as prominent theme in all the interviews. The discussion revolved around security and financial initiatives as driving factors for updating and developing AIS. Then ecology-focused usages emerged as a surprising aspect for some participants. The key ecological usages had an emphasis on developing ecological metrics aligning with the International Maritime Organization’s objectives. Interestingly, the financial focused usages also contributed to ecological improvements. In instance, savings in fuel and optimization of port activities also improve ecological aspects. Technology focused usages revolved around routing services, self-guided ships and the S100 and S200 standard product ideas.

The results of technical aspects of AIS were discussed in relation to VDES technology. Several limitations were identified including data quality, manually entered data, cybersecurity, update rate, radio coverage, and narrow radio band. While VDES system aims to address some of these issues such as cybersecurity and radio coverage, other challenges remain unchallenged as they are inherent to the current AIS technology.

Another matter of discussion was the implementation of the new VDES boxes, and the problems may be caused by the long-lasting implementation situation.

The new possible usages were driven by two key factors: financial considerations and legislative aspects. Financial objectives played a significant role in both motivating and discouraging technological development of AIS in the field. Additionally, the implementation of usually safety-focused new legislation served as a major driving force behind technical developments. Surprisingly, ecological aspect was seen as possible major motivating factor for next generation AIS.

The main findings indicate that the emergence of new AIS data usages are primarily driven by safety, financial and legislative requirements. Then VDES technology shows promise in resolving some of the technical limitations of AIS including data cybersecurity and bandwidth limitations. However, both AIS and VDES are used by the crew member and limitations depending on humans cannot be overcome solely with new technology and technological advancements. Furthermore, one central finding is that the complete implementation of VDES is expected to take several more years. This situation presents challenges for the parties in maritime sector who are seeking to adapt the new technology and establishing guidelines for its effective utilization. In summary, the findings present the driving forces behind the evolution of AIS data usages and the effects of VDES implementation when considering the technical limitations of AIS.

5.3 Research limitations and further research proposals

Generally, few limitations considering the results of this research should be discussed. Firstly, this research incorporated future research as part its scope. Firstly, future studies can be considered “value rational” meaning that participants’ values, approaches, and their personal purposes can influence the envisioned future scenarios (Aalto et al., 2022). These individual factors and personal purposes may impact the results of the research. Additionally, when conducting future-oriented research, it can be challenging to encourage the participants to think far ahead. To mitigate this, the researcher utilized PESTE framework to help participants broaden their perspectives. However, it should be noted that the future ideas and scenarios generated may have remained somewhat on the surface-level. The research faced challenges in encouraging interviewees to think abstractly and contemplate future possibilities, resulting the findings of future uses remaining on the surface level. It was difficult to push interviewees beyond their immediate and prompt them consider more futuristic scenarios. As a result, the insights gained from the interviews may have been limited to current state and the current developments of applications of AIS. This limitation highlights the importance of finding effective strategies to stimulate interviewees' thinking about futuristic scenarios.

Although this research was conducted as qualitative research and emphasized the quality of interviews over the quantity, the limited number of interviews does present some limitations regarding the generalizability of the findings. The research included five interviews. It is important to acknowledge that all the participants were focused on the maritime industry, which restricts the generalization of results to that specific field. Furthermore, four of the participants were Finnish companies and one was a Swedish company, suggesting that the findings may be more applicable to northern countries. While other background information was not gathered from the companies, it is possible that such information could impact the generalization of results. Furthermore, it is important to acknowledge that unintentionally, certain viewpoints may have been inadvertently omitted due to the selection of interview companies.

For the maritime field research this thesis has provided basis for the research of future usages of AIS in business and safety contexts. Additionally, it provides a basis for studying the technical characteristics of AIS and future developments of VDES. However, it is recommended that future research be conducted after implementation of VDES to assess its real-world impact. Furthermore, there is room for further exploration of the future usages of AIS data in various businesses contexts. Investigating the implementation process and examining the usage of VDES by the crew is recommended. This can involve studying the process and the experiences of the people using the system. By delving into these areas researchers can gain insights about the implementation and potential impact on the maritime industry. Also, after implementation and testing period it is interesting to research the use of new technical characteristics and any possible limitations of the new characteristics of VDES. Examining VDES technical advancements after implementation would provide valuable insights and contribute to the maritime research.

Understanding the diverse potential applications of AIS data and the possibilities of data utilization can serve as a catalyst for further developments of the technical characteristics. Moreover, studying the developments of VDES and the actual improvements of it in everyday life applications is essential for identifying the new possible needs for improvement and developments of the technology. While ideas such as automatic pilotage, self-driving ships, and automatic docking may currently seem more aspirational than immediately feasible, comprehending the possibilities and limitations of technology can help drive progress towards these objectives.

References

Aalto, Hanna-Kaisa – Heikkilä, Katariina – Keski-Pukkila, Pasi – Mäki, Maija – Pöllänen, Markus (2022) Tulevaisuudentutkimus tutuksi – Perusteita ja menetelmiä. Tulevaisuudentutkimuksen Verkostoakatemian julkaisuja 1/2022, Tulevaisuuden tutkimuskeskus, Turun yliopisto.

Alagha, Nader – Loge, Lars (2022) IJSC&N Special Issue "Opportunities and challenges of maritime VHF data exchange systems": Guest editorial message. *International journal of satellite communications and networking*.

Androjna, Andrej – Perkovic, Merko – Pavic, Ivica – Miskovic, Jaska (2021) AIS Data Vulnerability Indicated by a Spoofing Case-Study. *Applied sciences*, Vol. 11 (11), 5015.

Balduzzi, Marco – Pasta, Alessandro – Wilhoit, Kyle (2014) A security evaluation of AIS automated identification system. ASAC '14, Annual Computer Security Application Conference. 436-445.

Berns, Sjors – Vonck, Indra – Dickson, Rob – Dragt, Jochem – (2017) Smart ports. Point of view. Deloitte port services. The Netherlands. <https://www2.deloitte.com/content/dam/Deloitte/nl/Documents/energy-resources/deloitte-nl-er-port-services-smart-ports.pdf>, retrieved 30.1.2023.

Bhattacherjee, Anol (2012) Social science research: principles, methods, and practices. *Scholar Commons, University of South Florida*, 40.

Bulger, Monica – Taylor, Greg – Schroender, Ralph (2014) Data-Driven Business Models: Challenges and Opportunities of Big Data. Oxford Internet Institute. Research Councils UK: NEMODE, New Economic Models in the Digital Economy.

Chesbrough, Henry – Rosenbloom, Richard S. (2002) The role of business model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies. *Industrial and corporate change*, Vol. 11 (3), 529-555.

Delone, William – McLean, Ephraim (2003) The DeLone and McLean Model of Information Systems Success: A Ten-Year Update. *Journal of Management Information Systems*, Vol. 19 (4), 9-30.

DiCicco-Bloom, Barbara – Crabtree, Benjamin F. (2006) The qualitative research interview. *Medical Education*, Vol. 40 (4), 314-321.

Doumbia-Henry, Cleopatra (2018) Maritime Trade and Transport – An Outlook on the Issues and a Reflection on the Implications for Education and Research. 50 years of Review of Maritime Transport, 1968-2018: reflecting on the past, exploring the future. *United Nations Conference on Trade and Development*, No. 11, 52-54.

Dufva, Mikko (2022) Toimintaympäristön analyysi: PESTE ja sen variaatiot. Teoksessa Aalto, Hanna-Kaisa – Heikkilä, Katariina – Keski-Pukkila, Pasi – Mäki, Maija & Pöllänen, Markus (toim.) (2022) *Tulevaisuudentutkimus tutuksi – Perusteita ja menetelmiä.* Tulevaisuudentutkimuksen Verkostoakatemian julkaisuja 1/2022, Tulevaisuuden tutkimuskeskus, Turun yliopisto, 106-112.

Dufva, Mikko – Rekola, Sanna (2023) Megatrends 2023 - Understanding an era of surprises. SITRA studies 225, PunaMusta Oy, Helsinki.

Eriksson, Päivi – Kovalainen, Anne (2008) Qualitative methods in business research. Los Angeles, SAGE Publications Ltd.

EunSu, Lee – Amit J., Mokashi – Sang Young, Moon – GeunSub, Kim (2019) The maturity of Automatic Identification Systems (AIS) and Its Implications for Innovation. *Marine Science and Engineering*.

Fossey, Ellie – Harvey, Carol – Mcdermott, Fiona – Davidson, Larry (2002) Understanding and evaluating qualitative research. *Australasian psychiatry: bulletin of the Royal Australian and New Zealand College of Psychiatrists*, Vol. 36 (6), 717-732.

Fruhwirth, Michael – Ropposch, Christiana – Pammer-Schindler, Viktoria (2020) Supporting Data-Driven Business Model Innovations a Structured Literature Review on Tools and Methods. *Journal of Business Models*, Vol 8 (1), 7-25.

Golaya, Arun Pratap – Yogeswaran, Nithiyanandam (2018) “AIS 2.0”: Technological changes, implications and policy recommendations. *Maritime affairs*, Vol. 14 (2), 63-74.

Goudossis, Athanassios – Katsikas, Sokratis K. (2019) Towards a secure automatic identification system (AIS). *Journal of marine science and technology*, Vol. 24 (2), 410-423.

Gómez, Osvaldo – Barán, Benjamin (2004) relationship between Genetic Algorithms and Ant Colony Optimization Algorithms. Proceedings of CLEI2004. Latin-American Conference on Informatics, 766-776.

Greenwood, David – Khajeh-Hosseini, Ali – Smith, James – Sommerville, Ian (2010) The Cloud Adoption Toolkit: Addressing the Challenges of Cloud Adoption in Enterprise. Cloud Computing Co-laboratory, School of Computer Science, University of St Andrews, UK.

Harati-Mokhtari, Abbas – Wall, Alan – Brooks, Philip – Wang, Jin (2007) Automatic Identification System (AIS): data Reliability and Human Error Implications. *Journal of Navigation*, Vol. 60 (3), 373-389.

Heo, Y. – Yan, Thomas – Lim, Samsung – Rizos, Chris (2009) International standard GNSS real-time data formats and protocols. IGNSS Symposium 2009.

Hörteborn, Axel – Ringsberg, Jonas W. – Svanberg, Martin – Holm, Henrik (2019) A Revisit of Definition of the Ship Domain based on AIS Analysis. *Journal of Navigation*, Vol 72 (3), 777-794.

IALA, international Assosiation of Marine Aids to Navigation and Lighthouse Authorities (2023) S-200 Product specification and development status. <https://www.iala-aism.org/technical/data-modelling/iala-s-200-development-status/>, retrieved 5.5.2023.

IALA, International Association of Marine Aids to Navigation and Lighthouse Authorities (2017) G117 guideline, VHF data exchange system (VDES) overview. Edition 2.0, <https://navcen.uscg.gov/sites/default/files/pdf/AIS/IALA_G1117_Ed2_VHF_Data_Exchange_System_VDES_Overview_Dec2017.pdf>, retrieved 5.5.2023.

IHO, International Hydrographic Organization (2022) S-100 Universal Hydrographic Data Model. < https://iho.int/en/s-100-universal-hydrographic-data-model>, retrieved 17.4.2023.

Ilčev, Stojče Dimov (2017) Global mobile satellite communications theory: for maritime, land and aeronautical applications. Volume 1, Second edition. Springer.

IMO (1998) Resolution MSC. 74(69), Annex 1-3, Recommendation on Performance Standards for Universal Shipborne Automatic Identification Systems (AIS). <https://wwwcdn.imo.org/localresources/en/OurWork/Safety/Documents/AIS/Resolution%20MSC.74(69).pdf>, retrieved 1.11.2022.

IMO (2011) IMO’s work to cut GHG emissions from ships. <https://www.imo.org/en/MediaCentre/HotTopics/Pages/Cutting-GHG-emissions.aspx>, retrieved 18.4.2023.

IMO (2015) Resolution A.1106(29), Revised guidelines for the onboard operational use of shipborne automatic identification systems (AIS). <https://wwwcdn.imo.org/localresources/en/OurWork/Safety/Documents/AIS/Resolution%20A.1106(29).pdf>, retrieved 23.01.2023.

IMO (2022) Rules on ship carbon intensity and rating system enter into force. IMO regulations to introduce carbon intensity measures enter force on 1 November 2022. < https://www.imo.org/en/MediaCentre/PressBriefings/pages/CII-and-EEXI-entry-into-force.aspx>, retrieved 18.4.2023.

Iphar, Clément – Napoli, Aldo – Ray, Cyril (2015) Detection of false AIS messages for the improvement of maritime situational awareness. OCEANS 2015 – MTS/IEEE WASHINGTON, 1-7.

ITU-R (2014) Recommendation ITU-R M.1371-5. Technical characteristics for an automatic identification system using time division multiple access in VHF maritime mobile frequency band. <https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.1371-5-201402-I!!PDF-E.pdf>, retrieved 19.4.2023.

ITU-R (2022) Recommendation ITU-RM.2092-1. Technical characteristics for VHF data exchange system in the VHF maritime mobile band. <https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2092-1-202202-I!!PDF-E.pdf>, retrieved 4.4.2023.

Jacob, Stacy A. – Furgerson, S. Paige (2012) Writing Iterview Protocols and Conducting Interviews: Tips for Students New to the Field of Qualitative Research. *Qualitative report*, Vol. 17.

Kailash, Joshi (1991) A Model of User's Perspective on Change: The Case of Information Systems Technology Implementation. *MIS quarterly*, Vol. 15 (2), 229-242.

Kühne, Babett – Böhmann, Tilo (2019) Data-driven business models – building the bridge between data and value. ECIS 2019 Proceedings: Proceedings of the 27th European Conference on Information Systems (ECIS), Sweden, <https://www.researchgate.net/publication/332687256_Data-Driven_Business_Models_-_Building_the_Bridge_Between_Data_and_Value>, retrieved 8.5.2023.

Last, Phillip – Hering-Bertram, Martin – Linsen, lars (2015) How automatic identification system (AIS) antenna setup affects signal quality. Ocean engineering, Vol. 100, 83-89.

Lázaro, Francisco – Raulefs, Ronald – Wang, Wei – Clazzer, Federico – Plass, Simon (2019) VHF Data Exchange System (VDES): an enabling technology for maritime communications. *CEAS space journal*, Vol. 11 (1), 55-63.

Loredana, Nita – Iulian, Mihailescu (2017) Importance of Big Data in Maritime Transport. *Scientific Bulletin*, ("Mircea cel Bătrân" Naval Academy), Vol. 20 (1), 556.

Marine Accident Investigation Branch (MAIB) (2005a) Report on Investigation of the Collision between Hyundai and Sky Hope in the East China Sea on 21 June 2004. Report No 17/2005. <https://www.gov.uk/maib-reports/collision-between-container-vessels-hyundai-dominion-and-sky-hope-in-the-east-china-sea>, retrieved 8.2.2023.

Marine Traffic (2023) Ship tracking live map. <https://www.marinetraffic.com/en/ais/home/shipid:281955/zoom:10>, retrieved 5.5.2023.

Meyers, Steven D. – Azevedo, Laura – Luther, Mark E. (2021) A Scopus-based bibliometric study of maritime research involving the Automatic Identification System. *Transportation research interdisciplinary perspectives*, Vol 10, 100387.

Molina, N. – Cabrera, F. – Araña, Victor – Tichavska, M. (2020) An Overview About the Physical Layer of the VHF Data Exchange System (VDES). *Computer Aided Systems Theory – EUROCAST 2019*, Vol 12013, 67-74.

Osterwalder, Alexander – Pigneur, Yves (2010) Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers. Hoboken, NJ: John Wiley & Sons. *Journal of Product Innovation Management*, Vol. 29 (6), 1099-1100.

Pallotta, Giuliana – Horn, Steven – Braca, Paolo – Bryan, Karna (2014) Context-Enhanced Vessel Prediction Based on Ornstein-Uhlenbeck Processess Using Historical AIS Traffic Patterns: Real-World Experimental Results, *FUSION 2014 - 17th International Conference on Information Fusion*.

Park, Daewon – Park, Suhyun (2015) E-Navigation-supporting data management system for variant S-100 based data. *Multimedia tools and applications*, Vol. 74 (16), 6573-6588.

Parvinen, Petri – Pöyry, Essi – Gustafsson, Robin – Laitila, Miikka – Rossi, Matti (2020) Advancing data monetization and the creation of data-based business models. *Communications of the Association for Information Systems*, Vol. 47 (1), 25-49.

Phillip, Robert – Prause, Gunnar – Gerlitz, Laima (2019) Blockchain and Smart Contracts for Entrepreneurial Collaboration in maritime Supply Chains. *Transport and Telecommunication*, Vol 20 (4), 365-378.

Plaza-Hernández, Marta – Gil-González, Ana B. – Rodríguez-González, Sara – Prieto-Tejedor, Javier – Corchado-Rodríguez, Juan M. (2020) Integration of IoT Technologies in the Maritime Industry. *Distributed Computing and Artificial Intelligence*, Special Sessions, 17th International Conference, Vol 1242, 107-155.

Rong, H. – Texeira A.P. – Guedes Soares, C. (2022) Ship collision behaviour recognition and analysis on AIS data. *Ocean engineering*, Vol 245, 110479.

Royal Institution of Naval Architechts, RINA (2022) VDES promises a new era for maritime communications. *The Naval Architect.* <https://www.rina.org.uk/nofollow/iqs/dbitemid.2809/print.1/rp.4/sfa.view/rssnewsfeed.html>, retrieved 4.4.2023.

Patton, Michael Q. (2002) Qualitative research and evaluation methods (3rd ed.). Thousand Oaks (CA): Sage.

Puusa, Anu – Juuti, Pauli – Aaltio, Iiris (2020) Laadullisen tutkimuksen näkökulmat ja menetelmät. Gaudeamus.

Rachinger, Michael – Rauter, Romana – Müller – Vorraber, Wolfgang – Schirgi, Eva (2019) Digitalization and its influence on business model innovation. *Journal of manufacturing technology management*, Vol. 30 (8), 1143-1160.

Rong, Shijie – Li, Huiyuan – Xiang, Qian – Zhang, Zhe – Yin, Huihui (2021) Synchronization for VHF data Exchange System. *Journal of physics*. Conference series, Vol. 1952 (4), 42035.

RJWF (Robert Wood Johnson Foundation) (2008) Semi-structured Interviews. <http://www.qualres.org/HomeSemi-3629.html>, retrieved 27.3.2023.

Rüßmann, Michael – Lorenz, Markus – Gerbert, Philipp – Waldner, Manuela – Justus, Jan – Engel, Pascal – Harnisch, Michael (2015) Industry 4.0: The future of Productivity and Growth in Manufacturing Industries. Boston consulting group. 9 (1), 54-89.

Schwehr, Kurt (2011) Vessel Tracking Using the Automatic Identification System (AIS) During Emergency Response: Lessons from the Deepwater Horizon Incident. *Center for Coastal and Ocean mapping.*

Singh, Bablu – Vyas, Supriya (2020) Performance Comparison of Minimun Shift Keying and Gaussian Minimun Shif Keying in Additive White Gaussian Noise Environment. Intelligent Energy Management technologies, 277-283.

Sorescu, Alina (2017) Data-Driven Business Model Innovation. *The Journal of product innovation management*, Vol. 34 (5), 691-696.

Stephens, Stan (1994) Then & Now: Changes Since the Exxon Valdez oil Spill. Prevention, *Response and Oversight*, 301-309.

Sternula A/S (2022) VDES (AIS 2.0) – Affordable global connectivity. <https://www.sternula.com/vdes-ais-2-0/>, retrieved 4.4.2023.

Sun, Xiaowen – Hu, Qing – Jiang, Yi – Zhou, Mu – Mu, Zhou (2022) A Training Sequence-Based Ranging Method for R-Mode of VHF Data Exchange System. *Wireless communications and mobile computing*, Vol. 2022, 1-14.

Svanberg, Martin – Santén, Vendela – Hörteborn, Axel – Holm, Henrik – Finnsgård, Christian (2019) AIS in maritime research. *Marine Policy*, Vol. 106.

Teece, David (2018) Business models and dynamic capabilities. *Long range planning*, Vol. 51 (1), 40-49.

Tu, Enmei – Zhang, Guanghao – Rachmawati, Lily – Rajabally, Eshan – Huang, Guang-Bin (2018) Exploiting AIS Data for Intelligent Maritime Navigation: A Comprehensive Survey from Data to Methodology. *IEEE transactions on intelligent transportation systems*, Vol 19 (5), 1559-1582.

UNCTAD (2018) 50 Years of Review of Maritime Transport, 1968-2018: Reflecting on the past, exploring the future. United nations conference on trade and development. Transport and trade facilitation. Series No. 11.

U.S Committee on the Marine Transportation System (2019) Enhancing Accessibility and Usability of Automatic Identification System (AIS) Data: Across the Federal Government and for the Benefit of Public Stakeholders. *Washington, D.C.*

Welch, Catherine – Piekkari, Rebecca (2006) Crossing language Boundaries: Qualitative Interviewing in International Business. *Management international review*, Vol. 46 (4), 417-437.

Welch, Heather – Clavelle, Tyler – White, Timothy D. – Cimino, Megan A. – Van, Osdel Jennifer – Hochberg, Timothy – Kroodsma, David – Hazen, Elliot L. (2022) Hot spots of unseen fishing vessels. *Science advances*, Vol 8 (44), eabq2109-eabq2109.

White, Robert E. – Cooper, Karyn (2022) Qualitative research in the post-modern era: critical approaches and selected methodologies. Cham, Switzerland: Springer International Publishing.

Wimpenny, Gareth – Šafář, Jan – Grant, Alan – Bransby, Martin (2022) Securing the Automatic Identification System (AIS): Using public key cryptography to prevent spoofing whilst retaining backwards compatibility. *Journal of Navigation*. Vol. 75 (2), 333-345.

Wimpenny, Gareth – Šafář, Jan – Grant, Alan – Bransby, Martin – Ward, Nick (2018) Public Key Authentication for AIS and the VHF Data Exchange System (VDES). Proceedings of the 31st International Technical Meeting of the Satellite Division of The Institute of Navigation, Miami, Florida, 1841-1851.

Winther, Morten – Christensen, Jesper H. – Plejdrup, Marlene S. – Ravn, Erik S. – Eriksson, Ómar F. – Kristensen, Hans Otto (2014) Emission inventories for ships in the arctic based on satellite sampled AIS data, *Atmospheric Environment* 91, 1-14.

Wood, J. Philip (1995) OPA 90. *Maritime Policy and Management*, Routledge Taylor & Francis group 22:3, 201-208.

Wright, Darren – Janzen, Carol – Bochenek, Robert – Austin, Jessica – Page, Edward (2019) marine Observing Applications Using AIS: Automatic Identification System. *Frontiers in Marine Science*, Vol 6.

Yang, Dong – Lingxiao, Wu –Wang, Shuaian – Jia, Haiying – Li, Kevin X. (2019) How big data enriches maritime research – a critical review of Automatic Identification System (AIS) data applications. *Transport reviews*, Vol. 39 (6).

Zarzuelo, Ignacio – Soeane, María – Bermúdez, Beatriz (2020) Industry 4.0. I the port and maritime industry: A literature review. *Journal of industrial information integration*, Vol. 20, 100173.

Appendices

Appendix 1 Interview structure FIN/ENG

1. Kertoisitko itsestäsi hiukan. Mikä on työtehtäväsi ja miten AIS järjestelmä liittyy työnkuvaasi?
   // Would you like to tell us a little bit about yourself. What is the position you work at and what kind of role does AIS have in your work?

2. Minkälaisia merkittävimpiä käyttötarkoituksia teidän organisaatiollanne on AIS järjestelmälle tällä hetkellä?
   // What are the main current uses and applications your organization has for AIS?

3. Ajattele tilanne viiden vuoden päähän. Minkälaisia todellisia uusia käyttötarkoituksia AIS järjestelmällä voisi silloin olla?
   // Think of a scenario five years from now, what kind of new real potential uses could the AIS system have?

4. Miten AIS teknologian tulisi kehittyä viidessä vuodessa, jotta päästään tuohon?
   // How should AIS technology and data format develop in five years to achieve these new AIS uses?

5. Onko AIS teknologiassa tällä hetkellä selkeitä heikkoja kohtia, joiden vuoksi ei voitaisi päästä tuohon päämäärään?
   // Are there any clear challenges or weaknesses in AIS technology now, so that it would not be possible to reach the new AIS uses?

6. Mitä taloudellisesti tulisi ympäristössä tapahtua, että päästään näihin AIS käyttötarkoituksiin?
   // What should happen economically in the environment to allow these AIS uses?

7. Mitä ihmisten asenteissa tai koulutuksen osalta tulisi tapahtua, jotta päästään tuohon päämäärään?
   // What should happen in terms of people’s attitudes or education in order to reach that outcome?

8. Mitä meriliikenteen lainsäädännön osalta tulisi tapahtua, että tähän päästään?
   // What should happen in terms of maritime legislation to get to that outcome?

9. Mitä ympäristöön tai ekologisuuteen liittyen tulisi tapahtua, jotta päästään tuohon?
   // What should happen within five years in relation to the environment or ecological factors to get to the outcome?

10. Miten tulevaisuuden käyttötarkoitukset voisivat vaikuttaa ekologisuuteen ja luonnon huomioimiseen?
    // How could the future uses of AIS affect ecology and consideration of nature?

11. Nämä tekijät huomioiden tuleeko sinulle mieleen uusia käyttötarkoituksia, joita AIS:lla voisi olla noin viiden vuoden päästä tulevaisuudessa?
    // Considering these previous factors, can you think of any new uses that AIS could have in the upcoming five years?

Appendix 2 Research data management plan

Research data management plan for students

This document will help you plan how to manage your research data. More detailed instructions for each section are available online in the Research Data Management Guide for Students.

1. Research data

Research data refers to all the material with which the analysis and results of the research can be verified and reproduced. It may be, for example, various measurement results, data from surveys or interviews, recordings or videos, notes, software, source codes, biological samples, text samples, or collection data.

In the table below, list all the research data you use in your research. Note that the data may consist of several different types of data, so please remember to list all the different data types. List both digital and physical research data.

Research data type	**Contains personal details/information***	**I will gather/produce the data myself**	**Someone else has gathered/produced the data**	**Other notes**
Interviews		x		

* Personal details/information are all information based on which a person can be identified directly or indirectly, for example by connecting a specific piece of data to another, which makes identification possible. For more information about what data is considered personal go to the Office of the Finnish Data Protection Ombudsman's website

2. Processing personal data in research

If your data contains personal details/information, you are obliged to comply with the EU's General Data Protection Regulation (GDPR) and the Finnish Data Protection Act. For data that contains personal details, you must prepare a Data Protection Notice for your research participants and determine who is the controller for the research data.

I will prepare a Data Protection Notice** and give it to the research participants before collecting data ☒

The controller** for the personal details is the student themself ☒ the university ☐

My data does not contain any personal data ☒

** More information at the university's intranet page, Data Protection Guideline for Thesis Research

3. Permissions and rights related to the use of data

Find out what permissions and rights are involved in the use of the data. Consult your thesis supervisor, if necessary. Describe the use permissions and rights for each data type. You can add more data types to the list, if necessary.

3.1. Self-collected data

You may need separate permissions to use the data you collect or produce, both in research and in publishing the results. If you are archiving your data, remember to ask the research participants for the necessary permissions for archiving and further use of the data. Also, find out if the repository/archive you have selected requires written permissions from the participants.

Necessary permissions and how they are acquired

Data type 1: Interviews

- I will ask permission from the participants to use collected data

4. Storing the data during the research process

Where will you store your data during the research process?

In the university's network drive ☐
In the university-provided Seafile Cloud Service ☒
Other location, please specify: ☐

The university's data storage services will take care of data security and backup files automatically. If you choose to store your data somewhere other than in the services provided by the university, please specify how you will ensure data security and file backups. Remember to make sure you know every time where you are saving the edited/modified data.

If you are using a smartphone to record anything, please check in advance where the audio or video will be saved. If you are using commercial cloud services (iCloud, Dropbox, Google Drive, etc.) and your data contains personal data, make sure the information you provide in the Data Protection Notice about data migration matches your device settings. The use of commercial cloud services means the data will be transferred to third countries outside the EU.

5. Documenting the data and metadata

How would you describe your research data so that even an outsider or a person unfamiliar with it will understand what the data is? How would you help yourself recall years later what your data consists of?

5.1 Data documentation

Can you describe what has happened to your research data during the research process? Data documentation is essential when you try to track any changes made to the data.

To document the data, I will use:

A field/research journal ☐
A separate document where I will record the main points of the data, such as changes made, phases of analysis, and significance of variables ☒
A readme file linked to the data that describes the main points of the data ☐
Other, please specify: ☐

5.2 Data arrangement and integrity

How will you keep your data in order and intact, as well as prevent any accidental changes to it?

I will keep the original data files separate from the data I am using in the research process, so that I can always revert back to the original, if need be. ☒

Version control: I will plan before starting the research how I will name the different data versions and I will adhere to the plan consistently. ☒

I recognise the life span of the data from the beginning of the research and am already prepared for situations, where the data can alter unnoticed, for example while recording, transcribing, downloading, or in data conversions from one file format to another, etc. ☒

5.3 Metadata

Metadata is a description of you research data. Based on metadata someone unfamiliar with your data will understand what it consists of. Metadata should include, among others, the file name, location, file size, and information about the producer of the data. Will you require metadata?

I will save my data into an archive or a repository that will take care of the metadata for me. ☐

I will have to create the metadata myself, because the archive/repository where I am uploading the data requires it. ☐

I will not store my data into a public archive/repository, and therefore I will not need to create any metadata. ☒

6. Data after completing the research

You are responsible for the data even after the research process has ended. Make sure you will handle the data according to the agreements you have made. The university recommends a general retention period of five (5) years, with an exception for medical research data, where the retention period is 15 years. Personal data can only be stored as long as it is necessary. If you have agreed to destroy the data after a set time period, you are responsible for destroying the data, even if you no longer are a student at the university. Likewise, when using the university's online storage services, destroying the data is your responsibility.

What happens to your research data, when the research is completed?

If you will store the data, please identify where: University's provided Seafile Cloud Service for the future research.

Appendix 3 Letter to the interviewees

Hei,

Olen Turun kauppakorkeakoulussa tekemässä tutkimusta meriliikenteen AIS paikannusjärjestelmän tulevaisuudesta. Toivoisin päästä haastattelemaan yrityksessänne henkilöä, joka osaa vastata AIS järjestelmän käyttöön liittyvistä asioista.

Haastattelun tarkoituksena on tutustua siihen mihin AIS järjestelmää käytetään ja minkälaisia käyttötarkoituksia sillä voisi olla tulevaisuudessa. Tutkimuksen aihe on tärkeä automatisoituvan merenkulun vuoksi, sillä järjestelmien on kehityttävä toimialalla tapahtuvan kehityksen mukana.

Haastattelussa on tarkoitus käsitellä seuraavia teemoja:

- AIS järjestelmän tämänhetkiset käyttötarkoitukset
- AIS järjestelmän tulevaisuuden käyttötarkoitukset reunaehtojen mukaan
- Toimintaympäristön ehtojen kartoitus

Haastattelussa voidaan nostaa esille myös muita olennaisia aiheita. Haastattelun tavoitteellinen kesto on 45-60min.
Tietoja haastattelusta käytetään pro gradu -tutkielmassa ja osana laajempaa AIS tutkimusta Turun kauppakorkeakoulun Center of Collaborative Research tutkimuskeskuksessa. Kaikkea haastattelumateriaalia tullaan käsittelemään luottamuksellisesti, ja tutkimustulokset julkaistaan muodossa, jossa organisaatiotanne ei voida yksilöidä. Halutessanne voitte tarkastaa julkaistavan materiaalin etukäteen.

Mikäli koet, että organisaatiossanne on joku muu sopiva henkilö osallistumaan tutkimukseen, pyydän, että välittäisit tämän haastattelupyynnön kyseiselle henkilölle.

Vastaan mielelläni, mikäli sinulla on kysyttävää aiheesta.

Kiitos ajastanne ja panoksestanne.

Ystävällisin terveisin,
Emma Seppä

Appendix 4 Results diagrams

Table 10 Appendix results analysis

Coding	Subcategories	Categories: megatrendit
Just in time applications	**Data as a product**	**Turvallisuus/Security related usages**
Virtual arrival application	Two way communication	Filtering for AIS screen to filter small vessels away
Predictive navigation design	Port to port communication	Two way communication
Predictive applications	**Analyzed data**	Automatic collision avoidance tool
Port to port communication	New analytics about the situation	Port to port communication
Higher quality data utilization	Intelligent modelling about deviations	Intelligent modelling about deviations
S100 and S200 standard products	AI to detect black vessels	New analytics about the situation
Remote piloting	**Data-based services**	
Fuel optimization	Filtering for AIS screen to filter small vessels away	
New analytics about the situation	Automatic collision avoidance tool	
Intelligent modelling about deviations	**Data as a product**	**Ekologisuus/Ecological usages**
Port operations optimization	**Analyzed data**	Green ranking of ships
Automatic collision avoidance tool	Green ranking of ships	Green monitoring of ships
Self-guided ship	AI to detect pollution ejction	
Two way communication	**Data-based services**	
Green ranking of ships	Green monitoring of ships	
Green monitoring of ships	**Data as a product**	**Teknologia/Technological applications**
Filtering for AIS screen to filter small vessels away	Higher quality data utilization	Self-guided ship
Automatic docking	**Analyzed data**	Predictive navigation design
Routing services	Predictive navigation design	Predictive applications
	Predictive applications	Higher quality data utilization
	Data-based services	S100 and S200 standard products
	S100 and S200 standard products	Routing services
	Routing services	
	Self-guided ship	
	Data as a product	**Talous /Financial focused usages**
	Analyzed data	Fuel optimization
	Fuel optimization	Virtual arrival application
	Data-based services	Port operations optimization
	Just in time applications	Remote piloting
	Automatic docking	Automatic docking
	Remote piloting	Just in time applications
	Virtual arrival application	
	Port operations optimization	

Table 11 Appendix AIS VDES results analysis

Current problems in AIS	VDES aims to solve
Not accurate enough position data when docking	
Manually entered data unreliable	
ROT data not automatically available	
Cybersecurity problems	x
Update rate of position data	
Radio coverage problem	x
Only one antenna	
Radio range limitations	x
Limited amount of slots	x
Small data packages	x
Data format heavy for calculations	
Switching from satellite to coastal antenna	x
Open sourcing not availabe	
Narrow radio band	x
No authentication	x
Equipment has to be onboard	