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DIGITALIZING THE METHOD OF MONITORING AND REPORTING OF TEMPERATURE SENSITIVE CARGO UNITS

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The maritime, as a part of transport sector, is in transition. The traditional maritime industry is developing with digitalization. As an indication of this, is the development of autonomous ships which are being developed also in Finland. This thesis tried to find an improvement on the current practices of maritime work and describes one way to implement it. The thesis revealed possibilities of the digitalization and potential challenges. The thesis describes in general how the monitoring of temperature sensitive cargo units carried on board could be digitalized and studied the related theory. MS Finnstar, operated and managed by Finnlines Plc, was used as an example vessel for this thesis. Finnlines identifies itself as a leading shipping operator of ro-ro and passenger services in the Baltic Sea and the North Sea.

A survey was conducted for the thesis to find out the attitude of the vessels' crew to the current working methods of monitoring of temperature sensitive cargo units, to the development of the methods, and to the willingness to be involved in testing new methods. The result of the survey was that almost every one of the respondents felt that the current methods are somewhat clumsy and could be improved. Most of them were also willing to test new methods if it will not cause extra effort. For the thesis, the volunteered crew members were interviewed, the problems encountered in the current procedures were charted, and suggestions for improvements and ways to implement them were explored.

The development and digitalizing of the monitoring of temperature sensitive cargo units was divided into four sub-areas: infrastructure construction and equipment acquisitions, integration of the information systems currently used, development of the monitoring application, and utilization of the collected data. Infrastructure construction involved enabling telecommunication connections especially on cargo decks. Equipment purchases included the acquisition of WLAN access points to the cargo decks and the procurement of handheld devices for the monitoring application. The integration of the information systems, involved the use of the data from the existing information systems such as cargo data including temperature set point values and temperature deviation limits. The development of the monitoring application illustrated the most important features that correspond with the current methods, and remedies the perceived problems. The utilization of the collected data dealt with the sub-area, which creates added value to the owners of the example vessel. Benefits may come in overtime reduction for the crew which may allow longer resting periods, sharing the best practices between the vessels, problem reporting follow-up of the cargo units, improvement of the communication between vessels, office, and customers, as well as possibly by providing of new services to the customers.

LÄMPÖHERKKIEN LASTIYKSIKÖIDEN VALVONNAN DIGITALISOINTI

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Kuljetusala ja sen mukana merenkulku ovat murroksessa. Perinteisenä toimialana pidettyä merenkulkua pyritään kehittämään digitalisoitumisen myötä. Osoituksena tästä ovat autonomiset alukset, joita kehitetään myös Suomessa. Tämän opinnäytetyön tavoitteena oli havaita parannuskohde merenkulun työympäristöstä ja tuoda esille keino kehittää sitä. Opinnäytetyössä tuotiin esille digitalisaation antamia mahdollisuuksia ja mahdollisia sen mukana kohdattavia haasteita. Opinnäytetyössä kuvattiin yleisesti miten laivalla kuljetettavien lämpöherkkien lastiyksiköiden valvonta voitaisiin digitalisoida ja tutkittiin siihen liittyvää teoriaa. Opinnäytetyössä esimerkkialuksena käytettiin Finnlines Oyj:n operoimaa MS Finnstaria. Finnlines on merkittävä roro- ja matkustajaliikennevarustamo Itämeren ja Pohjanmeren alueella.

Opinnäytetyötä varten suoritettiin kyselytutkimus, jonka tarkoituksena oli kartoittaa laivalla työskentelevien suhtautumista lampöherkkien lastiyksiköiden valvonnan nykyisiin toimintatapoihin, niiden kehittämiseen sekä halukkuutta olla mukana testaamassa mahdollisia uusia toimintatapoja. Kyselytutkimuksen tuloksena oli, että lähes kaikki vastaajista kokevat nykyiset toimintavan jossain määrin kömpelöksi ja että kehitettävää löytyy. Suurin osa on myös valmis koekäyttämään uusia toimintatapoja mikäli niistä ei aiheudu ylimääräistä vaivaa. Opinnäytetyötä varten laivoilla haastateltiin työntekijöitä ja kartoitettiin nykyisissä toimintatavoissa kohdattavia ongelmatilanteita, sekä selvitettiin parannusehdotuksia ja keinoja niiden toteuttamiseen.

Lämpöherkkien lastiyksiköiden valvonnan kehitys ja digitalisointi jaettiin neljään osa-alueeseen: infrastruktuurin rakentaminen ja laitehankinnat, käytettävien tietojärjestelmien integraatio, valvontasovelluksen kehitys sekä kerätyn tiedon hyödyntäminen. Infrastruktuurin rakentaminen käsitti tietoliikenneyhteyksien mahdollistamisen laivalla, eritoten lastikansilla ja -ruumissa. Laitehankinnoilla käsitettiin tietoliikenneyhteydet lastiruumiin mahdollistavien WLAN tukiasemien hankinnat, sekä päätelaitteiden hankinnat valvontasovellusta varten laivoille. Käytettävien tietojärjestelmien integraatiossa käsiteltiin jo olemassa olevista tietojärjestelmistä saatavan informaation, kuten lastiyksiköiden lämpötilatietojen, hyödyntämistä. Valvontasovelluksen kehitys kuvasi tärkeimpiä ominaisuuksia mitkä vastaavat nykyisessä toimintavassa kohdattavia hyviä puolia sekä auttaa ehkäisemään siinä havaittavia ongelmatilanteita. Kerätyn tiedon hyödyntäminen käsitteli osa-aluetta mikä antaa lisäarvoa varustamolle. Hyödyt voivat ilmetä miehistön ylitöiden vähenemisenä mahdollistaen pitemmät lepoajat, toimintatapojen yhtenäistämisenä laivojen välillä, lastiyksiköiden ongelmaraportoinnin seurantana, tiedonkulun paranemisena laivan, maapuolen sekä asiakkaiden välillä, sekä mahdollisesti kokonaan uuden palvelun mahdollistamisena asiakkaille.

CONTENTS

1 GLOSSARY

Backend	The backend consist of a server side application and databases providing information and resources to the client user.
Charter	A party who makes agreement of transportation of the cargo with the shipper.
Digitalization	Digitalization can be considered to be general concept of the revolution of this era where operations and methods are simplified and enhanced by the digitized information.
Digitalizing	Digitalizing is applying the digitized information to simplify the specific operation.
Digitization	Digitization is the process of converting analog information into a digital computer readable format.
GNSS	Global Navigation Satellite System is the standard generic term for satellite navigation systems that provide autonomous geo-spatial positioning with global coverage. This term includes e.g. the GPS, GLONASS, Galileo, Beidou, and other regional systems.
GPRS	General Packet Radio Service is a packet oriented mobile data service on the 2G and 3G cellular communication system's global system for mobile communications.
ELE-unit	An ELE-unit is temperature sensitive cargo unit that has refrigeration or heating unit and it can be connected to vessel´s electric network.

LAN	A local-area network (LAN) is a computer network that spans a relatively small area. Most often, a LAN is confined to a single room, building, or group of buildings. However, one LAN can be connected to other LANs over any distance via telephone lines and radio waves.
Reefer	A refrigerated cargo container or semi-trailer used for transporting temperature sensitive goods.
Ro-ro vessel	Roll-on/roll-off vessels are designed to carry wheeled cargo. For example cars, trucks, semi-trailer trucks, trailers, and railroad cars, that are driven on and off the ship on their own wheels or using a platform vehicle.
Shipper	A party who receives the cargo from the charter and takes care of the transportation as agreed.
Wi-Fi	Type of WLAN that follows the IEEE 802.11 standards which most WLANs in use today do. Wi-Fi as a name for the standard is a trademark of the Wi-Fi Alliance.
WLAN	Any wireless local area network no matter what technology is used.

2 INTRODUCTION

Maritime industry is generally considered as a conservative compared to other industrial sectors when it comes to digital innovations. In maritime industry has been a digital development in port operations for a while. For example, the automatic gates with the identification of the registration plates in Vuosaari Harbour (Port of Helsinki Ltd 2018). Recently, digitalization has been undertaken to optimize and revolutionize the entire transport sector and thus reached also the shipping sector.

This thesis has been started on the basis of author´s personal interests and observations. The aim of this work is to provide added value to the client company by designing a way to digitalize the method of monitoring of temperature sensitive cargo units transported onboard. The principle of digitalizing the method of monitoring of temperature sensitive cargo units is that the paper lists used with current practices, will no longer to be used in any form neither onboard at sea or ashore when monitoring the units. The reasoning of digitalizing the method of monitoring of temperature sensitive cargo units is to streamline day-to-day work with the units, enable faster response to problem situations and long term monitoring of the units, improve the exchange of information between ship and land organizations and possibly achieve cost savings as a result of reduction of overtime.

MS Finnstar, operated and managed by Finnlines Plc, was used as an example vessel for this thesis. MS Finnstar is 218.8 meters long ro-ro passenger vessel. The vessel is able to carry 4 215 lane meters of cargo and 554 passengers (Finnlines Plc. MS Finnstar | Finnlines). MS Finnstar is operating between Helsinki and Travemünde with her two sister vessels MS Finnlady and MS Finnmaid (Finnlines Plc. Finnlines´ vessels). Her two other sister vessels are MS Finnswan and MS Europalink.

Picture 1. MS Finnstar (Finnlines Plc. MS Finnstar | Finnlines).

Finnlines identifies itself as a leading shipping operator of ro-ro and passenger services in the Baltic Sea and the North Sea. Finnlines is a part of the Grimaldi Group which is one of the world´s largest operators of ro-ro vessels. Finnlines provides also port services in Helsinki and Turku, which are the most important seaports in Finland. (Finnlines Plc. Information about Finnlines).

2.1 Objectives and research questions

The thesis aims to answer to the questions: How the current method of monitoring of temperature sensitive cargo units can be improved and optimized? What are the biggest problems of the current method and used practices and what are the possible benefits achieved by digitization?

In order to solve the research questions, the following questions will also be addressed: What are the different information systems and software the client organization uses in its activities? What information from the before-mentioned information systems can be utilized when digitalizing the method of monitoring of temperature sensitive cargo units?

The aim of this thesis is to determine the approximate cost level of digitalizing of the method of monitoring of temperature sensitive cargo units and to introduce one method of implementation that can be considered to be put into practice by the client. Writers' last goal is to increase the awareness on the operational and management level that such developments are feasible in the maritime industry.

2.2 Defining

The thesis deals with digitalization as a topical phenomenon. Substances related to maritime industry and areas related to the development site have been picked up for closer scrutiny.

The thesis deals material that may be sensitive to the client with great caution. As a result, this thesis is intended to be implemented in two versions, one of which should be only for the client.

2.3 Previous studies

Räisänen J. has studied maritime reefer transportation in his bachelor's thesis 2010. In his thesis Räisänen explored the development of the reefer industry from technical aspect. In his thesis Räisänen briefly describes the remote monitoring possibilities for the temperature sensitive cargo units. (Räisänen, 2010)

2.4 Research method

The research method was formed by a multi-strategic research aimed at transformation, where theory and practice alternate. The theory of the study came from the use of existing literature about digitalization and the active monitoring of related articles in the field. Expert interview was used to enable a wider understanding and application of the underlying theory. D.Sc. (Tech.) Jussi Turkka enabled access to his research results on network technologies and guided in the practical use of the theory with his special expertise in the field.

For the study, employees at the operational level were interviewed to present the issues of the current practices of temperature monitoring and to refine the development ideas. Listening to the experiences and views of the people in the field of practical work makes it possible to identify the problems encountered in everyday work.

The willingness of the deck departments of Finnlines to take part in testing for the use of the digitalized method of the monitoring of temperature sensitive cargo units was surveyed by a questionnaire. The survey contained 4 multiple choice questions, which also surveyed users' views on the current method, the need for digitalization and the willingness to share their views and development ideas on the subject. The survey is presented in Appendix 1 (Appendix 1).

The personnel from the booking department and claims handling department of the client company were interviewed. By interviewing personnel from the booking department, the reasons why the information of the cargo units to be loaded is changing so late, even during loading, were clarified. In many cases the driver who brings the cargo unit to the loading port, has the latest information about the cargo and confirms or corrects the values entered in to the booking system. Charters also have possibility to alter the cargo data in the booking system via the interface built for them. By interviewing personnel from the claims handling department, the biggest issues with claims according to the temperature sensitive cargos were resolved. The amount of the claims, were kept down by active communication with vessels and by frequently updated instructions.

3 DIGITALIZATION

Digitalization, aka digitalizing, is the process of converting information into a digital format that can be read easily by a computer. Digitalization is making the information in digital format easily accessible for use across various platforms, devices, and interfaces. (Irniger, A. 2017).

The great breakthroughs in information technology and telecommunications in the last century have opened the way for us to see digitalization as a new, large, general-purpose technology that alters the way to work and produce commodities. (Lehti, M., Rossi, M. 2017).

3.1 The impact of digitalization on business

"Everything that can be digitized will be digitized"
-Paul Krugman the winner of the Nobel Prize in economics, 2008.

New, productive practices and business models based on digital knowledge revolutionize trade, healthcare, teaching and other services. In developed countries, the services already cover more than 70 percent of the national income. Digitalization challenges formerly local services to global competition - and it also makes it possible to expand regionally, including for export. Trade in digital services is the fastest growing sector in world trade, and according to OECD statistics, more than half of Finland's exports of goods are from service exports. (Mattila, V-M. 2017).

Digitalization rebuilds business processes and models. In addition to digitalization that streamlines and improves existing business, the change will enable unprecedented business that is inspired by innovations and new services such as the Internet of Things, Robotics, Augmented Reality and Artificial Intelligence. Internet phenomena enable new earnings and business logics. Industrial jobs are transformed into service jobs and at the same time the boundaries between industries and markets are blurred. Digitalization enables the use of physical objects, equipment, buildings, traffic and other infrastructure to change from ownership to service. (Mattila, V-M. 2017).

An increasing part of the value of physical products comes from information about their activities and the services that are exploited. Owning physical factors of production does not guarantee success. The world's largest hotel chain, Hilton, owns over half a million hotel rooms and has hundreds of thousands of employees. Yet under a thousand employees, Airbnb is able to challenge the hotel chain, deliver the same number of rooms, and as a company it is more valuable than Hilton. (Mattila, V-M. 2017).

3.2 Harnessing digitalization for business

The core of the exploitation of digitalization is how the organization can use its own creativity, i.e. to understand which tools are most useful to the particular organization in each situation. The development target may include marketing, sales, product or service development, production, need for change in the current business, or a whole new business. The technologies that make the digital revolution happen are all already there. (Mattila, V-M. 2017).

In a digitalized world, succeeds the one who is constantly observing their environment, understands the opportunities, and experiment with new operating models and possibilities. Technologies for experimentation are often readily available as cloud services. If successful, the service can be quickly deployed and scaled according to the demand. (Mattila, V-M. 2017).

3.3 Digitalization in shipping

Maritime sector has been regarded as a very conservative and passive sector where progress is slow (Vogdrup-Schmidt L., ShippingWatch, 2015). The deficiencies and limitations of information exchange in maritime sector are perceived as ineffectiveness of shipping. In Baltic Sea traffic, ships spend 40% of their time in ports because of the "first come - first served" slot allocation system and 40% of the vessels sails in the ballast condition because there is no suitable cargo found (Sundell, Napa).

In recent years, technological development has also brought digitalization into the maritime sector. Examples of this are Maersk's and IBM's joint venture in research of utilizing blockchains in global trade and digitizing supply chains (Nguyen L., 2018) as well as competition in the development of autonomous ships. Rolls-Royce's goal is to embark the first ocean-going autonomous vessel in 2025. Kongsberg and Yara's goal is to deploy the first fully electric and autonomous container ship, which starts as manned and will be reducing the crew's need during the deployment with the goal of being fully autonomous in 2020. (Walker, J. 2018).

4 CONNECTIVITY AT SEA

The Internet connection at sea has limitations depending on the technology used for enabling the connectivity onboard. Mobile network coverage has limitations depending on vessels´ distance from the shore line and satellite connection has limitations according to the sea areas and therefore may have limitations on availability of the useable satellites.

4.1 Mobile network coverage and mobile data at sea

4.1.1 Mobile network coverage

The theoretical maximum range of a cell network, based on a tall mast and flat terrain, may possible be between 50 and 70 km (25–40 nautical miles). Some technologies, such as GSM, have an additional absolute maximum range of 35 km (19 nautical miles), which is imposed by technical limitations. (ETSI SMG Plenary No. 28 2018).

4.1.2 Factors affecting the coverage and improving the coverage

The variation in the coverage and the gaps in the coverage area are characteristics related to the structure of the mobile networks. The coverage can vary in the same location at different times of the day and year, even during a single telephone call or internet connection.

The coverage is affected by the user's location in relation to the nearest base station. Typically, the signal between the base station and the terminal device is strong in the vicinity of the base station. The signal becomes weaker as the distance grows, as well as the connection is disrupted by the buildings, vegetation, altitude differences between the base station and the terminal device, and even weather conditions in the area. User movement during the connection can affect the connection quality as the network coverage changes as well. Weak signal and discontinuous or slow connection is possible to improve with an additional outdoor antenna. (Viestintävirasto, Finnish Communications Regulatory Authority 2018).

4.1.3 Mobile network coverage at sea

At sea the mobile connection is often interrupted or is not available at all. Figure 1 shows indicative coverage areas of the mobile network in the Baltic Sea. At sea, the visibility and usability of a mobile connection is largely affected by the vessel´s distance to the shore, the vessel´s movement and the weather conditions.

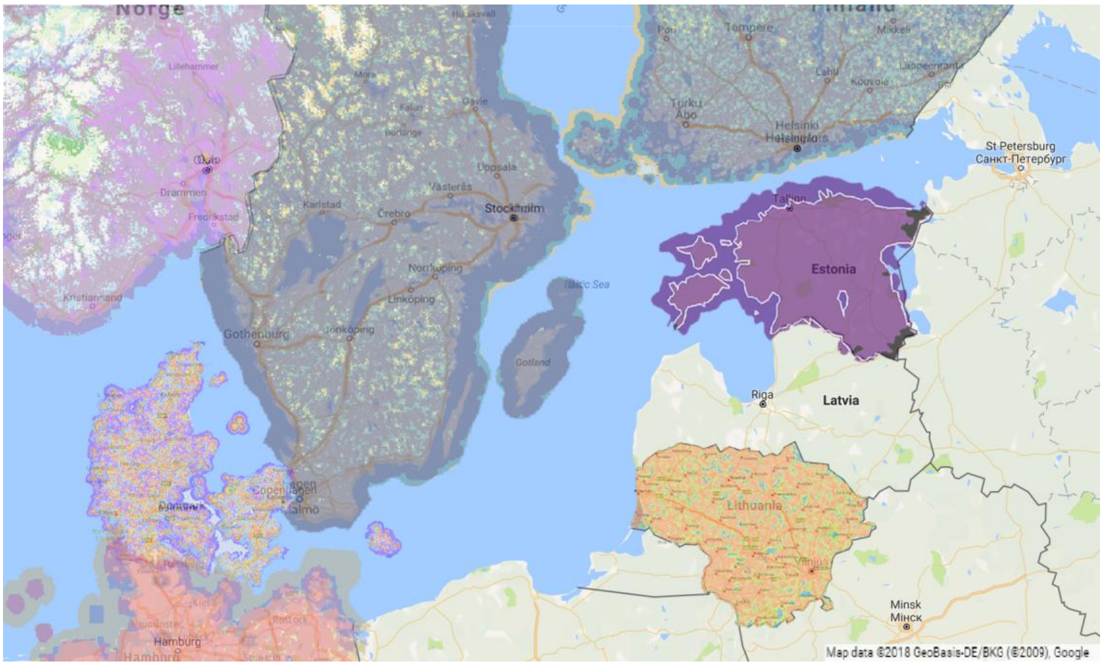


Figure 1. Mobile network coverage in the Baltic Sea. (Map data: GeoBasis-DE/BKG, Google)

Note: The mobile network coverage areas shown in Figure 1 are merely indicative and this figure is only made for illustrating the gaps on mobile network coverage. Based on the figure it is not desirable to compare the different service providers. The data has been collected from the referenced service providers and added to the map layout provided by GeoBasis-DE/BKG, Google. (Mobile network coverage maps).

4.1.4 Mobile network at port and on coastal area

When a vessel is in port or near to the coast, mobile connections can be utilized where cell towers are nearby available. It should be borne in mind that mobile connections can cause huge costs on a country and contract basis. Vessels that often operate in the same ports can have a data plan with the network service providers in that region.

4.2 Satellite connection

At sea, the largest network coverage is achieved, with the exception in Polar Regions, by satellite antennas. The weakness of a satellite connection is the relatively expensive price and slow connections. Satellite connection is susceptible to disturbances caused by major directional changes, which are usually temporary. Placement of the satellite antenna can cause blind spots in some directions, which can be prevented by multiplying the number of satellite antennas. Satellite data communication systems are very common in shipping.

4.3 Network coverage onboard

The ship´s movement, shape, metal structure and other radio equipment, such as radar, can cause interference in the functionality of the mobile connections. The network coverage of personal devices such as mobile phones across the ship varies greatly. Generally, the best coverage on the ship is on the outer decks and on the bridge. The weakest coverage is usually in the engine room, and on cargo decks and cargo holds. The latter often do not have coverage at all when closed, due to solid metal structure of the vessel.

4.3.1 Local area network onboard

Due to the ship´s structure, establishing a connection between different compartments should be built using the local area network. Depending on usage requirements, distances and thickness of the structures as well as the regulations, wired and wireless solutions are used to extend the local area network.

4.3.2 Wireless network coverage on cargo decks

Sharing the ship's Internet connection to cargo decks and cargo holds on wireless local area network (Wi-Fi) is uncommon. There are possibly Wi-Fi arrangements in accommodation areas onboard, but rarely any Wi-Fi coverage has been extended to the cargo decks. On the cargo decks, interference with the wireless connection is caused by the cargo itself and also by the metal structure of the cargo deck.

To illustrate the coverage of the wireless network on the cargo deck, measurements were performed. In the measurements, the Wi-Fi signal strength was measured on the cargo deck, which was full of semi-trailers and containers loaded in rows.

MS Finnstar, operated and managed by Finnlines Plc, was used as an example vessel for the measurements. The vessel contains three cargo decks and one cargo hold. Temperature sensitive cargo units can be loaded on all three cargo decks, where the cargo units can be plugged to the vessel´s electric network. The uppermost cargo deck is open-air cargo deck, aka weather deck, and the two other cargo decks below are closed during the sea voyage. The measurements were performed on the closed cargo deck.

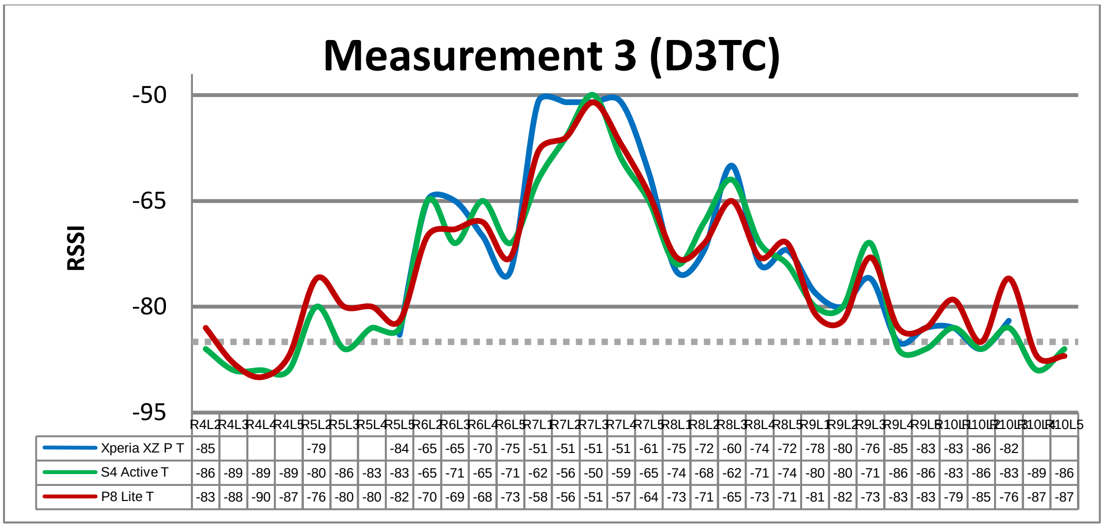
4.3.2.1 Wi-Fi coverage measurements on cargo deck

In determining the usefulness of the wireless network on the cargo deck, it is necessary to be able to compare signal strengths. Two different transmitters, the Wi-Fi base stations, were used for the measurements. For the measurements, the transmitters were placed on the cargo deck and in cargo offices next to the cargo deck. Three different smartphones were used for measuring the signal strengths. Received signal strength indicator (RSSI) value is relative and its interpretation depends on the device manufacturers and background noise. (Speed Guide, Inc 2018).

Another of the Wi-Fi base stations was battery powered and small in size, enabling it to be easier to place high in the hold. However, this model has a poor transmit power, so in the measurements were also used traditional Wi-Fi base station equipped with two external antennas and it was powered by AC power.

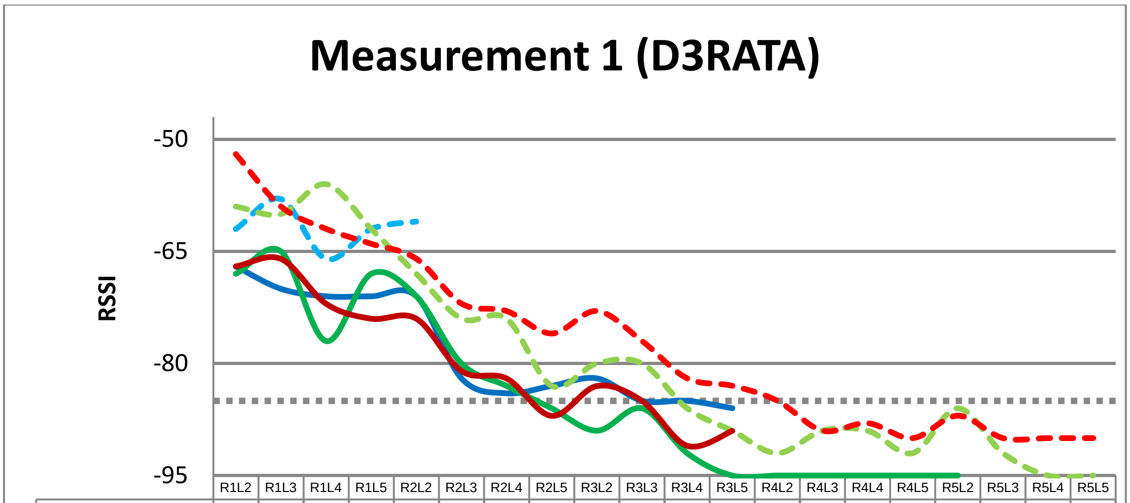
Picture 1. Picture of portable battery powered Wi-Fi base station used on Wi-Fi signal strength measurements.

Figure 2 shows that received signal strength indicator (RSSI) value drops below -80 db when distance to Wi-Fi base station grows and between the transmitter and receiver were two rows of cargo. Figure 3 shows, that RSSI value with the stronger transmitter is 5 – 10 db stronger than with the weaker transmitter. As a conclusion it can be estimated that useable Wi-Fi coverage on cargo deck with full cargo of semi-trailers and containers loaded in rows reaches over three rows of cargo.



	R4L2	R4L3	R4L4	R4L5	R5L2	R5L3	R5L4	R5L5	R6L2	R6L3	R6L4	R6L5	R7L1	R7L2	R7L3	R7L4	R7L5	R8L1	R8L2	R8L3	R8L4	R8L5	R9L1	R9L2	R9L3	R9L4	R9L5	R10L1	R10L2	R10L3	R10L4	R10L5
Xperia XZ P T	-85				-79			-84	-65	-65	-70	-75	-51	-51	-51	-51	-61	-75	-72	-60	-74	-72	-78	-80	-76	-85	-83	-83	-86	-82		
S4 Active T	-86	-89	-89	-89	-80	-86	-83	-83	-65	-71	-65	-71	-62	-56	-50	-59	-65	-74	-68	-62	-71	-74	-80	-80	-71	-86	-86	-83	-86	-83	-89	-86
P8 Lite T	-83	-88	-90	-87	-76	-80	-80	-82	-70	-69	-68	-73	-58	-56	-51	-57	-64	-73	-71	-65	-73	-71	-81	-82	-73	-83	-83	-79	-85	-76	-87	-87

Figure 2. Wi-Fi signal strength measurements on cargo deck in full cargo condition with Wi-Fi base station equipped with weak antenna (T) positioned above the center of the cargo deck (C).



	R1L2	R1L3	R1L4	R1L5	R2L2	R2L3	R2L4	R2L5	R3L2	R3L3	R3L4	R3L5	R4L2	R4L3	R4L4	R4L5	R5L2	R5L3	R5L4	R5L5
Xperia XZ P R	-62	-58	-66	-62	-61															
Xperia XZ P T	-67	-70	-71	-71	-71	-82	-84	-83	-82	-85	-85	-86								
S4 Active R	-59	-60	-56	-62	-68	-74	-74	-83	-80	-80	-86	-89	-92	-89	-89	-92	-86	-92	-95	-95
S4 Active T	-68	-65	-77	-68	-71	-80	-83	-86	-89	-86	-92	-95	-95	-95	-95	-95	-95			
P8 Lite R	-52	-59	-62	-64	-66	-72	-73	-76	-73	-77	-82	-83	-85	-89	-88	-90	-87	-90	-90	-90
P8 Lite T	-67	-66	-72	-74	-74	-81	-82	-87	-83	-85	-91	-89								

Figure 3. Wi-Fi signal strength measurements on cargo deck in full cargo condition with Wi-Fi base station equipped with strong antenna (R) and Wi-Fi base station equipped with weak antenna (T) positioned in the cargo office (A).

5 DETERMINING LOCATION OF MOBILE DEVICE

Mobile device positioning is utilized in many cases, such as emergencies, navigation, work management, and targeted advertising. The most familiar positioning method for mobile device is satellite based solution Global Position System (GPS), more generally Global Navigation Satellite System (GNSS). GNSS positioning is poorly applicable to urban environments where are densely high buildings as well as indoors when often there is no connection to the satellites.

In these situations, the diversity of wireless networks, such as cellular base stations for coarse location estimation, and WLAN access points for more accurate location estimation, are used. Utilizing WLAN positioning is common because there are plenty of WLAN access points, especially in urban environments. WLAN access points can be utilized for positioning using, for example, proximity or trilateration estimation strategy, where the location of the access points needs to be known in advance. In the proximity approach, the location is based on the location of the most strongly received signal source. Trilateration requires the location of the three WLAN access points that are used to estimate the location of the device. In addition, wireless signals can be utilized in location estimation by radio frequency fingerprinting, where received signal strengths and identifiers are compared to the pre-collected signal data. (Mondal, R. U., Ristaniemi T., Turkka J. August, 2017).

5.1 Radio frequency fingerprinting

Radio frequency (RF) fingerprinting is based on the idea that every single location in urban environment has a unique radio network environment i.e. fingerprint. RF fingerprinting utilizes cell information and radio measurements for location estimation.
Received signal strengths from several WLAN access points are compared to the measurement data previously collected during the teaching phase. Received signal strengths measured during the teaching phase with WLAN access point identification data are stored in the database with accurate location information. The advantage of RF fingerprinting is that it does not require advance information about the locations of installed WLAN access points, such is needed with trilateration. The disadvantage is that RF fingerprinting requires time-consuming data collection teaching phase be-

fore the user´s location can be estimated. If the details of WLAN access point installations, such as location information, are known, it is possible to build an automatic solution for measuring data collection. The accuracy of position estimation is affected by distances, directions, and transmission powers of nearby WLAN access points, as well as the number of WLAN access points available. (Hiltunen T., Turkka J., Mondal R., Ristaniemi T.).

5.1.1 The impact of access points on the accuracy of RF fingerprinting location estimation

Outdoor field tests have shown that the accuracy of 67 % probability location estimation of RF fingerprinting technique improved from 88.2 to 49.5 meters with a single WLAN access point along with LTE (1800 MHz) base stations when reference was made to the technique that used only LTE base stations. The location provided by the satellite positioning was used in the field tests as a benchmark for location estimation and for error determination. Where multiple WLAN access points were available, the utilization of the ten most powerful received signal strengths of WLAN access points will reduce 74% of the location error compared to the technique that used only LTE base stations. Using the ten most powerful received signal strengths from WLAN access points with LTE base stations a 23.32-meter 68% probability location estimation accuracy was achieved. (Hiltunen T., Mondal R. U., Turkka J., and Ristaniemi T.).

Measurement Type	Max. number of measured WLAN IDs	68 %-ile PE [m]	95 %-ile PE [m]
WLAN + LTE (1800 MHz)	All WLAN APs	22.42	47.78
	23	22.51	48.27
	18	22.65	48.10
	13	23.14	48.21
	10	23.32	48.60
	5	26.80	57.57
	2	35.43	80.52
	1	49.41	127.67
LTE (1800 MHz)	LTE BSs only	88.29	235.45

Table 1. Number of measured access points (AP) affecting to positioning error (PE) (Hiltunen T., Mondal R. U., Turkka J., and Ristaniemi T.).

Observations of indoor tests shows that, where multiple WLAN access points were available, utilizing more than ten WLAN access points does not significantly improve positioning accuracy (Laitinen E., Lohan E. S., Talvitie J., and Shrestha, S. March, 2012). Similar conclusions can be seen from outdoor field test measurement results shown in table 1.

6 WHAT IS DIGITALIZED?

6.1 Temperature sensitive cargo units

In the Baltic Sea traffic temperature sensitive cargoes are transported in containers, tank containers and semi-trailers that are equipped with refrigeration and / or heating equipment. Semi-trailers and containers with refrigerated equipments are called reefers. Reefers are generally powered by external electric source when they are waiting to be loaded on quay side or loaded onboard. When transported over the road or by rails, they can be powered by diesel powered generators. Reefer manufacturers are, for example Carrier, Thermo King, and Daikin (Alconet Containers). Temperature sensitive cargo is also transported at sea by refrigerated ships which have electrical distribution equipment for powering each container's cooling system (Port Technology, 2018).

Picture X. Picture of reefer container (Seatrade Maritime News, 2013).

Picture X. Picture of reefer semi-trailer (for-sale - Central California Truck & Trailer Sales - Sacramento).

According to statistics provided by Finnlines, temperature sensitive cargo units form a significant part of the container and semi-trailer traffic in the Baltic Sea region. Globally, temperature sensitive cargo has been in growing role despite the financial challenges (Drewry, 2014). With the exception of other types of cargo, the prices of temperature sensitive cargo have risen (Drewry Maritime Research, 2018).

6.2 Temperature sensitive cargo types

Typical temperature-controlled cargo types are fresh products such as fruit, meat, fish, vegetables, dairy products, and other foods. Also non-food products are transported as temperature-controlled like flowers, plants, and pharmaceuticals.

6.2.1 Pharmaceuticals

Pharmaceutical cargo types are medicals, human organs, blood, health care instruments, and other health care products. Pharmaceutical industries have been growing over the past decade. Global cold chain logistics of pharmaceutical products have been estimated to be worth of $13.4 billion in 2017 and estimation for 2021 is $16.6 billion. (Winnesota Regional Transportation, 2018)

According statistics of World Health Organization (WHO), Parental Drug Association (PDA) and other industry estimates, *almost 20 % of temperature sensitive health care products are damaged during transport due to a broken cold chain.* (Thermo King, TK PharmaSolutions).

6.3 The importance of the monitoring system

As the quantity and quality requirements of transportation of the products grow, there is an increasing demand for the development of monitoring systems. The monitoring systems may increase safety of the crew, reduce workload, and especially to prevent cargo contamination and deterioration. (Wang, L., Kwok, W. H., 2010).

It is approximated that 35 % of the vegetables and fruits are spoiled during transportation. 10 – 15 % of the meat and fish products are estimated to be deteriorated. The value of decayed products is so high that it raises the total costs of transportation. To make transportation of the products more effective and reliable, more advanced monitoring systems are developed to reduce the spoilage of the transported products. (Wang, L., Kwok, W. H., 2010).

North P&I Club has investigated *that a significant proportion of reefer cargo damage is caused by long periods of time off-power, at terminals or during inland transit, as well as malfunctioning refrigeration units* (Seatrade Maritime News, 2013).

Temperature deviations within reefer containers can also be caused by improper stowage affecting airflow, stuffing of warm cargo, heat generated by premature ripening of the cargo and incorrectly set parameters, says the club in its guides 'The Cold Chain' and 'Refrigerated Containers' (Seatrade Maritime News, 2013).

6.4 Remote monitoring services

There are services for remote monitoring of temperature sensitive cargo units. By remote monitoring user is enabled temperature data monitoring, as well as changes in the settings of the unit at distance. Remote monitoring is possible through the mobile network. Some of the service providers also promote the use of a satellite connection.

The disadvantages of remote monitoring are that the functionality of the service onboard is limited to units loaded on outer cargo decks and in many cases only in coastal area. In addition, remote monitoring services usually only supports units of a specific manufacturer.

The TracKing is monitoring application provided by Thermo King that enables refrigerated trailer tracking. The application shows the location of the unit and enables to manage the cargo temperature and respond to the alarms of the unit. (Thermo King, 2018)

The ColdChainView is cold chain monitoring web application that is optimized to work with ORBCOMM´s Euroscan-branded temperature recorders and modules. The ColdChainView enables real-time monitoring and management of the temperature modules connected when the unit is reachable. According to manufacturer, components build by ORBCOMM use satellite and cellular connectivity. (ORBCOMM Inc.).

6.5 Monitoring of the temperature sensitive cargo onboard

The employees onboard inspect the proper functioning of the incoming temperature sensitive cargo unit, check the temperature setting and the current temperature and mark those down to the monitoring list. The monitoring list is a paper list that contains the temperature setting values and temperature limit values of the temperature sensitive cargo units, on that moment the list is created. Often, some of this information changes, for example during the loading. Most commonly changes are additional units to the list, or removal of unit from the list, as well as changes in the temperature data of some of the units on the list. These changes are generally observed when the temperature sensitive unit is loaded onboard or by the active list updating and monitoring of the officer who is responsible for the loading. Sometimes a notification or a confirmation request about the changes is coming from the customer´s representative, agent, or booking department.

During the sea voyage, the employee onboard performs monitoring of temperature sensitive cargo units that are not accompanied by customer´s representative, i.e. monitoring rounds. The purpose of the monitoring round is to detect any deviations in temperature and check proper operation of the unit and vessel´s electricity distribution. Time of the observation, observed temperatures, and malfunctions are written on the paper list, which is inspected by the supervisor at the end of the round.

6.6 Why it should be digitalized?

The aim of digitalizing the method of monitoring temperature sensitive cargo units is that the paper lists related to the aforementioned units would not be needed in any form at sea or ashore. At sea, the benefits are focused on enhancing everyday routines, as well as ashore to improve access to information and analyzing the used practices. For customers, digitalizing the method of monitoring of temperature sensitive cargo units can, if needed, create a completely new service concept.

6.6.1 Benefits

At sea, the benefits are focused on enhancing everyday recurring actions and therefore reduce the workload and enable longer resting periods, and also enable quality control and standardization of working practices between vessels. Workers onboard would always have access to the latest information about the cargo units, manufacturer and device-specific operating instructions and alarm lists, and instructions of operating procedures.

Ashore, there is a possibility to get almost real-time observations made onboard. This will enable a faster response to queries of a specific temperature sensitive cargo unit, even in the long term. From digitized data, it is possible to easily construct automated long-term statistics. It is possible to analyze, harmonize, and optimize operating procedures between different vessels through the information gathered on board when comparing timestamps, number of problem situations, and related information.

For customers, it would be possible to build own service enabling access to customer-owned temperature sensitive cargo units' observations, problems, and other notes related. In such a case, the customers can uninterruptedly track their units at sea. Long-term statistics of the behavior and number of malfunctions caused by temperature sensitive cargo units can provide to customers valuable information about the unit's maintenance needs. The customer could be given the possibility to change the units' settings and for other messaging, that is currently being done by e-mail through the booking department ashore, with the vessel via monitoring application.

6.6.2 Challenges

6.6.2.1 Costs and deployment of the system

When moving to the new system, investments are required for covering new costs, such as equipment purchases and installation work, as well as development work. Additionally, users need to familiarize themselves with the new system. The users (seafarers) of the system being planned are in a very different skill level to use digital tools and services. Due to the varying skill level of users and the challenging maritime conditions, the equipment being used is subject to considerable stress. Devices should therefore be particularly durable and spare devices should be available. Additionally, users' opinion on the new system should be resolved to prevent potential problems.

6.6.2.2 Security issues

Whenever information is stored or transmitted digitally, there is a risk that the information will end up in the wrong hands. As an exception to paper lists, it is possible to get access to electronic data from at distance. When designing a new system, security should be at the center of development. When mapping the security risks of the new system, the risks inherent in the existing systems should also be taken into account. If there are already existing security holes in the existing systems, they may also cause security issues when commissioning the new system. If the security of the existing systems has been carefully handled, then the existing security practices can possibly be utilized with the implementation of the new system.

It can never be completely excluded that the data won’t end up to unauthorized users, so in designing the systems and databases it is most important to think what data is genuinely necessary. It is necessary to evaluate which information can cause damage in the wrong hands and which is less susceptible to misuse. In addition, the recorded information needs to be in readable form only for the systems intended to be used. Obviously, all communications between different systems must be encrypted.

It is also necessary to distinguish between user groups that only have access to the information they need in their work. Customer related information should be handled and stored in accordance with current laws and regulations.

7 THE CURRENT PRACTICES FOR MONITORING THE TEMPERATURE SENSITIVE CARGO UNITS

The on-duty officer is able to request and print an up-to-date list of temperature sensitive cargo units. The list printed by the ship can be obtained via the booking program. The program builds a list of temperature sensitive cargo units of the data entered by the customer into the program via the interface made for them, as well as the data entered by the employees of the booking department. On board, a remote request is made to the booking program, which will send a list of temperature sensitive cargo units by e-mail. There are two types of lists available the monitoring list and the reporting form. The monitoring list is intended for monitoring of the temperature cargo units and the reporting form is for reporting, i.e., for problem situations. These paper lists are key elements of the current practices.

7.1.1 The monitoring list

The monitoring list has the incoming temperature sensitive cargo units ordered by alphabetically. The monitoring list contains unit specific information such as the name of the customer company, the type of the product, the temperature setting, and the allowed temperature deviation range, if entered into the booking system. The on-duty officer on board checks on the list whether there are any units with special requirements such as particularly sensitive products that require uninterrupted cooling or heating, whose temperature fluctuations should be kept to a minimum. Finally, the list is handed over to the deck hand.

7.1.2 The reporting form

The reporting form includes the name of the customer company, contact information for problem situations, the type of the product, the temperature setting, and the allowed temperature deviation range, if it has been entered into the booking system. The form will be filled, if there are malfunctions or other problems with the temperature sensitive cargo unit and the customer´s representative is contacted.

7.2 Instructions to vessels

The operating instructions of the temperature control of the cargo units carried onboard are based on current guidelines and the text style in the following description of the operating instructions is in accordance with the instructions to avoid any confusion.

The ELE-unit in this context equals the definition of the temperature sensitive cargo unit.

7.2.1 Temperature control of reefer units

An ELE-unit should not be left without monitoring more than four to six-hours onboard. The four to six-hour rule for temperature checks applies also during loading and discharging.

For safety reasons, it is not allowed to use the ELE-units' diesel engines onboard because of the risk of fire. In case of unexpected situations or emergency, diesel engines may be run on master's order.

7.2.1.1 At port – loading

The diesel engine of the ELE-unit should be switched off before loading onboard. If is not it is to be switched off immediately. The ELE-unit must be plugged into the ship's electrical network without delay when loaded onboard. The required temperatures and settings, given in the monitoring list, have to be checked before plugging in and the monitored readings entered in the monitoring list. After plugging in, it is to be checked that the unit is running.

If the shipper's representative (for example lorry driver) accompanies the unit, it is his duty to plug the unit into the ship's electrical network provided by the ship's crew and ensure that the ELE-unit is working properly and check the right temperature and settings for the unit.

In case of malfunction of the ELE-unit or if the temperature range limits or settings does not correspond the information given in the reporting form the agent in the port of loading has to be contacted for further actions. If the agent can't be reached the emergency contact of the shipper is to be contacted directly for further advice.

Units with malfunction or with incorrect temperatures or settings are not accepted onboard and are to be left ashore.

7.2.1.2 At sea – during voyage

A record of the monitored temperature readings has to be kept during the sea voyage. The observations are to be entered in the monitoring list at four to six-hour intervals. For safety reasons, all lorries containing hazardous cargo that are connected to ship's electrical network are to be checked by the ship's crew as any other ELE-unit.

7.2.1.3 At port – discharging

Before the unit is unplugged from the ship's electrical network the unloading schedule has to be checked with the agents and stevedores to minimize the time the units are without electricity. A unit should not be without electricity for more than two hours before discharged. Attention shall be paid to the effect of different circumstances such as the type of cargo and outside temperature that can radically shorten the time the ELE-unit can be without power.

The unplugging temperature is to be entered in the monitoring list. The diesel engines of ELE-units shall not be switched on by the ship's crew. Units accompanied by the shippers' representatives are also to be unplugged by the ship's crew unless the representative hasn't explicitly expressed his will to be present during unplugging.

7.2.1.4 In case of malfunction

If malfunction is noted or the temperatures are not within the allowed limits, the shipper or his representative must be contacted at once by using the emergency contact information provided in the Booking and reporting form. If a shippers' representative (for example lorry driver) accompanies the unit he or she shall be informed instead. Any repairs except those under emergency situation are to be undertaken only with consultation with the shipper's emergency contact.

Any attempts to contact the shipper or his representative and the content of the subsequent discussion or actions taken (including reasons why) by the vessel have to be documented, primarily in the reporting form.

7.2.2 Temperature control of heated tank units

7.2.2.1 Temperature control possibility

The possibility of monitoring the temperature of the substance in the tank shall be check out before the heated unit is connected to ships electricity supply. The unit not fitted with a thermometer is not loaded on board.

In such cases the vessel is to contact the booking department to inform about the unit. The shipper is entitled to re-book the unit without electricity supply i.e. as a normal unit. Without consent of re-book the unit must be left ashore and the shipper must be informed accordingly.

7.2.2.2 Temperature differences

Once on board and in case the temperature in the tank unit does not correspond with the information given in the monitoring list and in the reporting form the shipper emergency contact must be contacted for instructions by all means.

In case shippers representative can’t be reached and shippers instructions are not available extensive over heating of the substance in the tank unit must be avoided by manually controlling the temperature by disconnecting the unit from the electricity supply to avoid possible over flow of substance or damage to the product. This is particularly important with the units carrying dangerous substances which may react violently in too high temperatures.

Any attempts to contact the shipper and subsequent content of the discussion or actions taken including reasons by the vessel, has to be entered into the vessel’s documents. Ship shall never repair or change parts in the heated tank units without direct instructions from the shipper.

7.3 Current practices on board

7.3.1 Connecting, monitoring and disconnecting the temperature sensitive cargo units

At the arrival of the temperature sensitive cargo unit, the ship´s crew member onboard ensures that the unit is in the monitoring list, connects the unit to ships electric network with a thick electric cable, checks the correct operation of the unit, and records the connecting temperature on the monitoring list. In addition, the worker checks the monitoring list for specific requirements for the unit.

During a sea voyage, the vessel's employee goes through the monitoring rounds to check the temperature sensitive cargo unit's temperature and correct operation. Monitoring rounds are carried out every 4-6 hours at sea.

Before the temperature sensitive cargo unit is unloaded from the ship, the vessel's employee checks the operation of the unit and records the disconnection temperature and disconnects the unit from the ship's electric network.

In all cases temperature deviations, malfunctions, and related problems are recorded to the monitoring list and reported to the supervisor onboard. In case of problems, the customer or its representative is informed by supervisor. Finally, the lists and copies of the lists are archived onboard, in addition the related documents of the units with observed problems are sent to the office for further clarification.

7.4 Problems encountered in the current practices

The paper lists related to the temperature sensitive cargo units are valid only at the time of creation of the list. Often, also during loading, minor changes occur in the quantities or temperature settings of the units and the changes are usually recorded to the monitoring list manually. In some cases the changes are significant enough and the lists are reprinted, so the temperatures and observations already marked previously should be moved to the new list. However, the list containing the original entries should also be retained, leading to several piles of paper.

During loading, there is often several temperature sensitive cargo units loaded onboard same time, whereby the worker rushes to browse and fill the monitoring list, lower it down, handle the electrical cable, and connects the unit to ship´s electrical network. When in such a hurry, the browsing of the monitoring list is felt to be time consuming and clumsy, leading to a need for an extra pair of hands. In these situations workers off-duty are to be emerged to help with the rush.

Handwritten markings have fluctuations due to markers, which repeatedly cause at least mild interpretation problems. In addition, working conditions onboard are challenging for the paper list. In combination with moisture, wind and dirt, the top pages of the monitoring lists are partially unreadable. There are even cases where the wind has squashed the monitoring list to the sea, when all current observations of the voyage have disappeared.

Picture 2. Example of dirty monitoring list after loading.

The paper lists related to the temperature sensitive cargo units are archived on board three months after the voyage for possible future clarifications. Such archives are bulky and the readability of dirty and moisture-exposed lists may not remain good. In addition, archives has to be physical accessible when resolving the problems afterwards.

8 DEVELOPMENT IDEAS FROM THE OPERATIONAL LEVEL

8.1 Survey

For the thesis, survey was made to map the attitude of employees working with the temperature sensitive cargo units to the current system and methods, to the possible new system, as well as the willingness to participate to test the possible new system.

The main target group of the questionnaire consisted of deck repairmen, able-bodied seamen, and ordinary seamen of the crew, and chief mates of the officers of the Star-class vessels in Helsinki – Travemünde traffic. The calculated optimal number of responses for the questionnaire was 12 responses per ship. In total, 29 responses were received from all the vessels included. However, the response rate (81 %) couldn’t be accurately defined because some of the respondents may have been also outside from the main target group, as no one was explicitly banned from answering to the questionnaire. However, those workers who have not been or will not be working with temperature sensitive cargo units more than occasionally were excluded from the survey. After all, the number of responses to the questionnaire was satisfactory.

86 % of survey respondents felt the need for development for of the current system and 52% were dissatisfied with the current approach. With one exception, all respondents felt positive for the digitization of the temperature monitoring system. About half of the respondents (47 %) were somewhat concerned about the problems and challenges of digitization. Based on the interviews, the biggest concern relates to the possible extra work due to digitization or the technical challenges of the system, such as battery life of the portable device.

26 (93 %) of the respondents were willing to test the possible new system. However 29 % of the respondents, on condition that it will not cause extra work. Half of the respondents were willing to share their own experiences or development ideas for the possible new system.

8.2 Interviews

During the autumn 2017 and spring 2018, interviews of the operational level showed generally the need for digitizing and developing the method of monitoring of temperature sensitive cargo units. Some of the interviewees had the opinion that, despite the need for the development, the current system fully or almost fully corresponds to customers' expectations and requirements. While most of the interviewees felt that the current system does not correspond to the demands and expectations of the customers especially with the present amount of temperature sensitive cargo units carried onboard.

There was major concern with the interviewees about the possible increase in workload due to the transition to the new system. In addition, the durability of the devices in terms of battery life and challenging maritime conditions has been considered as potential problems. There was also concern about oversight of the employees who will be executing the monitoring rounds.

As one of the primary benefits of the new system, interviewees expected to get rid of the paper handling, which has been felt to be extremely clumsy under the maritime conditions. The availability of up-to-date unit data was considered to be one of the biggest positive changes that could be achieved by digitization of the current system.

One of the proposals as an improvement to the current system was that the minimum and maximum temperature of the temperature sensitive cargo unit to be monitored would be compulsory information when the unit is being booked to the intended voyage.

The features requested by the interviewees for the new system were the functional and easily approached interface for the monitoring application used on the handheld device as well as the ability to check and read the alarm codes with explanations and instructions for the refrigeration units of different manufacturers. There has been discussion about the possibility of obtaining the temperature data from the unit via the connected electrical cable as it is done on large container ships. Different wireless communication possibilities for acquiring the temperature data from the carried units were also discussed with the interviewees. Such arrangements need to have standardizations and support from the manufacturers of the refrigeration devices used on temperature sensitive cargo units.

The personnel from the booking department and claims handling department of the client company were also interviewed. By interviewing personnel from the booking department, the reasons why cargo information is changing so late, even during loading, were clarified. In many cases the driver who brings the cargo unit to the loading port, has the latest information about the cargo and confirms or corrects the values entered in to the booking system. Customers have also possibility to alter the cargo data in the booking system via the interface built for them.

By interviewing personnel from the claims handling department, the biggest issues with claims according to the temperature sensitive cargos were resolved. The amount of the claims, were kept down by active communication with vessels and by frequently updated operating instructions. About different technical solutions and approaches for digitizing the method of monitoring temperature sensitive cargo were also discussed with the personnel from the claims handling department. It was pointed out that some similar solutions have been explored earlier.

9 DEVELOPING THE MONITORING SYSTEM FOR TEMPERATURE SENSITIVE CARGO

The system to be developed can be divided into four categories: Integration and development of backend systems, improving vessel´s network infrastructure and selection of handheld device, development of monitoring application and utilization of collected data.

9.1 Integration and development of backend systems

Integration of backend systems means utilizing the data from existing cargo booking systems by enabling data exchange between different systems. This is done by utilizing either the existing system databases or by building a new more flexible system, which databases can be used to share the data, acquired from the current backend systems, to the systems to be developed.

9.1.1 Integration of the booking system

The booking system is software, where the ship owners' employees enter the voyage specific data of temperature sensitive cargo; for example, temperature settings and limits, type of the cargo, and contact information for problem situations. This information from customers is desired to be in black and white, for example in written by e-mail. In some cases, some information needs to be refined by telephone or otherwise orally, for example from the representative of the client company supplying the cargo unit when the unit arrives to the loading port.

Client companies also have the option to enter the data to their temperature sensitive cargo units into the booking system via the web interface. The booking software acquires the data, entered by the customers to the web interface, to its databases.

9.1.2 Database for the temperature sensitive cargo

The cargo information of the booking system has to be stored to the database, where the monitoring application for temperature sensitive cargo should be able to make voyage-specific database requests and thus keep the monitoring application up-to-date. The monitoring application should make database update requests at certain intervals, for example every 10 minutes. In addition, whenever there are changes for the information in the booking system for the selected voyage, a notification should be sent to the monitoring application. Then the application would know to make database update request and download the latest temperature sensitive cargo information. The best result will be achieved by combining different techniques.

It is necessary to build a separate database where the collected data and observations of temperature sensitive cargo by the monitoring application will be stored. By using this database the system would enable to inspect voyage-specific observations of the specific temperature sensitive cargo unit afterwards. Also the database would enable the construction of long-term tracking statistics, for example, according to specified cargo unit or vessel.

In the second phase of development of the system, customers could have access to the data of their temperature sensitive cargo units via the interface build for them to this new system. The customer would see the latest observations of his units and, if necessary, pass on requests to the vessel where the unit is loaded for changes to temperature settings, or other requests and enquiries related to his units. In addition, the information of potential problems related to his units could be sent via this new system to the client's awareness for waiting for the acknowledgment and further actions.

9.1.3 Integration of the stowage planning system

The stowage planning system is an application used by stevedores, allowing user to track which cargo units has been loaded onboard and on which cargo deck they have been loaded. In the stowage planning system is stored, among other things, the type of cargo unit, registration number, length, width, and weight of the unit, the class information of dangerous cargo the unit contains, and information of the need for electrical connection and the location onboard. In addition, the stowage planning system has map layouts for cargo decks for the vessel to be loaded.

The location data of the cargo unit from the stowage planning system constructs from deck number, loading direction, lane number, and position number on the current lane. The location of the unit is calculated by using all cargo units' lengths before the current unit on the current lane.

The location data of the temperature sensitive unit from the stowage planning system could be utilized in the monitoring application. In such a case, it would be possible to build a location-based search function based on the map of the cargo deck. In addition, the information about which cargo deck the unit has been loaded is essential for performing the temperature monitoring and solving problems occurred with temperature sensitive cargo units.

In the current method of monitoring the temperature sensitive cargo units, the stowage planning system has been used to determine if a certain unit has been loaded onboard when no markings has been entered for the unit to the monitoring lists.

Occasionally there are cases when cargo unit is booked as temperature sensitive and it is loaded finally as non-temperature sensitive cargo unit. Information about this change is not always shared between booking department, stevedores, and vessels' crew. Additionally there are cases when customer queries is their cargo unit loaded onboard and is the specified unit loaded as temperature sensitive cargo unit. In cases like this it is common way to check the location info of the cargo unit from stowage planning system and therefore speed-up locating the cargo unit onboard and visually check correctness of the information according to the cargo unit.

9.2 Improving ship network infrastructure and selection of the handheld device

From the point of view of the effective and flexible operation of temperature monitoring system, it is essential that the ship has functional Internet connection. The options are the utilization of the Internet connections of the handheld devices or enabling access to the Internet connection onboard. The latter means, eventually, functional Wi-Fi network inside the vessel. Internet connection options onboard are based on mobile and satellite connections. The most comprehensive result is achieved by combining different communication technologies.

9.2.1 Utilizing the mobile data connection of the handheld device

When a ship is in a port, it is possible to utilize the mobile data connection of the handheld device. The strength of this is the use of the band independent of the ship's connection and the high-speed connections in a good coverage area. Weaknesses are its inactivity at sea and especially in cargo holds and decks. Additionally, this connection type may cause additional costs per device. In practice this option would be impracticable as a standalone solution, requiring good mobile network coverage to the vicinity of shores.

9.2.2 Utilizing the ship's mobile connections

When the ship is in coastal area, mobile connections can be utilized where there are cell towers nearby. This range can be improved by the good positioning of the antennas onboard and the versatile use of different mobile technologies. The strengths of exploiting such a system are the sharing of the same large data plan among multiple users, as well as high-speed connections in good coverage areas. The downside is the limited range of mobile networks depending on the distance to the cell towers. In addition, mobile connections may cause large costs for data traffic on a contractual basis.

9.2.3 Utilizing the ship's satellite connection

At sea, the most extensive Internet connection is available, with the exception of the Polar Regions, by satellite connection. The strength of satellite connection is therefore coverage. The weaknesses are expensive and comparatively slow connections.

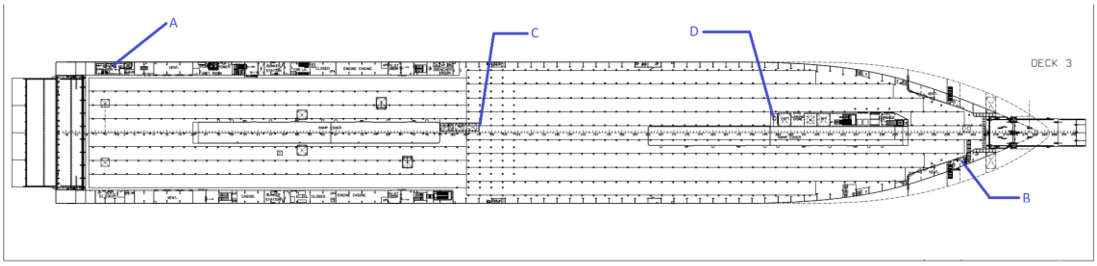
The satellite connection is also susceptible to disturbances in major changes in direction of the vessel, which are usually momentary. The positioning of an antenna can cause blind spots in some directions, which can be prevented by multiplying the satellite antennas.

9.2.4 The ship’s wireless local area network

Sharing the ship's Internet connection to the handheld device is done by wireless local area network (Wi-Fi). There are possibly Wi-Fi arrangements in accommodation areas on board, but rarely any Wi-Fi coverage has been extended to the cargo decks. Uninterrupted communication between the handheld device and the background systems requires the Wi-Fi network to be extended to the cargo decks.

As a minimum requirement, that can be considered, is covering the cargo deck 3 by Wi-Fi network with at least a single base station. In addition, it would be good to have a Wi-Fi connection on the bridge, whereby the transmission of the data of the monitored observations of temperature sensitive cargo units with the background system would be effective during the sea voyage.

The best case would be that the cargo decks 3, 5, and 7 would be covered with more than one Wi-Fi base stations and Wi-Fi repeaters to maximize the coverage areas and minimize disturbances in the data transmission. In addition, a comprehensive Wi-Fi network can be used to utilize location information of the handheld device. Estimation for a comprehensive Wi-Fi network on the cargo decks 3 and 5 means 3 to 4, and on the cargo deck 7 means 2 to 3 Wi-Fi base stations and Wi-Fi repeaters.



Picture 3. An example of covering the cargo deck 3 with Internet connection by placing four Wi-Fi base stations and Wi-Fi repeaters. Wi-Fi base stations A and B are placed inside the cargo offices.

9.2.5 Selection of the handheld device

For the monitoring rounds, the ship should have at least one handheld device and a spare device. In the optimal solution, handheld devices would be available for each cargo deck, where is expected to be temperature sensitive cargo units, plus additional one for the supervisor and one as a spare device.

The criteria for the handheld device selection are suitability for the maritime environment, to meet the needs of daily use, availability, and price. The maritime environment requires the handheld device to withstand dirt, moisture, and small knocks. The criteria to meet the needs of daily use are wireless connectivity, large capacity battery, user-friendly and a functional interface, and that the device possibly has few physical buttons. Availability means that the device already exists on the market and, if necessary, can be replaced later by more suitable model.

In practice, the implementation of a flexible system requires smartphone or tablet as handheld device. For its size, a smartphone may be more suitable for practical work. The device's durability against dirt and moisture limits handheld device options for devices working on Android operating system instead of iOS. This option is also favored by the price and the possible replacement of the device by another model if necessary.

9.3 Development of the monitoring application

The monitoring application is the key factor in digitalizing of the method of monitoring of temperature sensitive cargo units. The operational sector is approximately going to enter more than 100,000 observations per year to the monitoring application, so the application should be as practicable and reliable as possible. Data entered in the application is transferred to the backend systems, enabling backups and data processing from ashore.

9.3.1 Choice of development platform

The features required by the application, determines the development platform where the application is meaningful to be implemented. Development platforms are being improved all the time and there has been a strong emphasis on ways to develop software without the actual programming skills. Which in practice means templates that are used for simple and sometimes more complicated applications to be built from prefabricated interchangeable code blocks. Such programming is called modular programming.

There is no need to use the monitoring application in non-Android operating systems, so cross-platform support is not necessary to maintain. The monitoring application's features are largely well-suited for general use, with the exception of possible programming of the keystrokes (physical buttons) and the use of indoor positioning techniques.

9.3.1.1 Native mobile applications

Native mobile applications are written in a programming language that has the full support of the operating system (OS) manufacturer. For Android applications, the official programming languages are Java, C#, and Kotlin (Google LLC 2018, Kotlin and Android). The strengths of native applications are numerous, up-to-date and official libraries. The native code is compiled into the operating system without any extra translators and the compile does not result in performance losses. The weakness is the lack of the cross-platform support for different operating systems. Android Studio is the most widely used native application development platform for Android OS. (Fifty Pixels Ltd 2018).

9.3.1.2 Hybrid applications

Hybrid applications are applications written and compiled in a separate programming platform, which appears to the users as native applications of their platform. As a programming language, network programming languages such as HTML, CSS, and JavaScript are generally used. Hybrid applications´ strength is the cross-platform support, where the same program code can be directly or almost directly compiled operating on different operating systems, such as Android, iOS or web-side services. Weaknesses are inadequate programming libraries and thus access to some features of the device may be limited. In addition, hybrid applications suffer from performance losses when building more complex programs. (Auth0 – Blog 2018).

In the Internet hybrid application development platforms are promoted, especially with the ability to produce software without the actual programming. Typically, there is a graphical user interface for design platform on the web, which aims to get from program design to the proof of concept level as quickly as possible and with little programming as possible. The development platforms for hybrid applications are mostly based on Cordova. (The Apache Software Foundation 2018).

9.3.1.3 Native-like mobile applications

Somewhat misleadingly, so called native applications seek to achieve the cross-platform benefits of hybrid applications and minimize performance losses when compiling the program. Despite the non-native code, the program appears on the operating system as a native program, and in the opt-out case performance losses are not generated, such as with hybrid applications. However, such programs are constrained by the limited number of supported programming libraries. The limitation of such applications could be bypassed by building support for native libraries in the programming platform. However, support for native libraries is also somewhat limited, and access to the latest libraries is very poor. The native libraries are adding more complexity to the native-like application with result where programmer has to learn and understand the native and native-like programming languages. That is leading to a result where the benefits of the cross-platform support are lost to the complexity and increased skill demands for a programmer. One of the most widely spreading development platforms like this is React Native, developed by Facebook Inc, which syntax is synonymous with JavaScript. (Facebook Inc 2018).

9.3.2 The features of the monitoring application

The most important features of the monitoring application are reliable data transfer with backend systems and the usability of the application in the operating environment.

9.3.2.1 Transfer of voyage specific cargo data to the monitoring application

The monitoring application should be able to retrieve voyage based data from the backend system. It should be possible to perform request operations manually. Additionally, changes in information according to the selected voyage in the backend systems should be provided as updates to the monitoring application via, for example, a push notification (Urban Airship, Inc 2018). The push notification may include only notification of the changes, whereby the monitoring application knows to execute an update request. Or the push notification can be used to deliver the updates to the selected voyage. In addition, when the monitoring application is active, it is advisable to do update requests for the backend system, for example, every 15 minutes, for any changes. However, it should be noted that the operating system version of the handheld device imposes restrictions on certain time interval requests and push notification reception. The latest operating systems are generally designed to be more energy efficient, and this is on the Android side done so that the requests of applications running background are attempted to stack simultaneously, allowing the device to remain uninterrupted for longer periods in non-active mode. (Google LLC 2018, Optimize for Doze and App Standby).

9.3.2.2 Temperature observations and problem reporting

All observation information should remain as log entries with timestamp for the backend system. Also, mistakes and modifications must remain their own markings. In the aftermath of troubleshooting situations, it is a prerequisite that all events are available in databases. This requires database tables where all the entries from current unit are to be found.

There should be database table for temperature observations, where only the corrected data is available, where illustrative graphs can be constructed from these observations, where errors made by the user do not interfere with the statistics. If this table also includes incorrect and later corrected temperature observations, there should be a separate column to indicate that the information is incorrect. This column may contain a reference to the corrected observation or otherwise be empty. It should be noted that observations for the same unit can be made accidental or deliberately almost at the same time, due to more than one terminal and user, so it should not be assumed that the corrected data is always the next observation data of the current unit. In that case, when a particular observation is corrected, reference is to be made to that exact referenced observation.

Temperature observations should be able to be flexibly and efficiently entered to the system. First, before entering the observations, user should be able to quickly select the correct cargo unit. The choice of the desired cargo unit in the monitoring application should be flexible and the search functions to be intelligent and intuitive. The voyage specific cargo units should be shown in the list view, where from user can select and see a detailed view of the unit. The list view should be able to be arranged by alphabetically, and according to the previous observations. Each list view should also be able to display in reverse order for practical reasons. The list views should be able to be grouped, for example, by unit type.

Picture 4. An example picture for entering the temperature observations.

The cargo units should be able to be retrieved by the characters on registration numbers. The search function should generate a list, where you can choose to input the observations for selected unit. By default, the first result of the list can be provided for the purpose of entering observations.

An example of smart search is a search for the characters contained in the registration number of the cargo unit, where the units whose registration number matches the search sequences in the same order sequentially starting from the first character will be on the top on search results. The following units that come in the search results that have the search string in the same order, starting with the first of the following characters. Also, search results may include more units including the characters in the search, but the characters are not sequential or the order of the characters is different from the input.

Picture 5. An example picture of smart search functionality and list view.

Observations about malfunctions and other problem situations end up in the backend system as log entries. Observations of deviations and malfunctions are displayed to the user with visual symbols and colors so that they are easily noticeable by the supervisor. The monitoring application may include operating instructions to known problem situations such as a change of faulty cable or check of fuse. User should be able to enter log entry for performed actions.

Deviations and problem situations are to be reported to the customer's representative according to the instructed procedures. As an enhanced service, the customer could receive notifications of the problem and the taken measures from the monitoring application.

9.3.2.3 Use of location information

The location information of temperature sensitive cargo unit can be used to locate the desired unit on the map layout or, for example, based on user location information. Unit location information can accelerate the search for a particular unit if it is needed to find for closer inspection.

The stowage planning system has been used to determine the location of a particular temperature sensitive cargo unit. The system to be developed should be able to access the location information on the stowage planning system, either directly or through an interface built for this purpose. The information on the stowage planning system is entered by the stevedores and may contain inaccuracies and errors.

WLAN access points may be used to determine the user's location if they are placed sufficiently dense on cargo decks. The user's location information can be utilized, for example, during the loading phase, allowing the unit to be given an indicative location when user enters the unit's data into the system.

In addition, the user should be given the opportunity to manually enter the unit's position, for example, on the map layout of the cargo deck. Comparison of different spatial data sources may be utilized when searching for a unit for closer inspection.

9.3.2.4 Exchange of observations

Sending of observations to the backend system from the monitoring application is carried out via the Internet using the ship's network infrastructure. Communication should be reliable and happen as often as possible when reasonable without draining the battery. The observation timestamp can be utilized when avoiding saving the same observation to the same unit for several time, aka duplicates, when multiple handhelds collects and sends observations. The observations made, must also be exchanged between the handhelds that are logged on and used to monitor the observations of the units on the same voyage.

9.4 Utilization of collected data

The collected data of temperature sensitive cargo unit should be transferred as resiliently and reliably as possible to the databases of backend systems. Different user groups can utilize the collected data for different purposes. The meaningfulness of the system's digitization depends largely on how its data is utilized for commercial purposes.

9.4.1 User groups

Dividing users in different level of groups enables limit the access of different users to only relevant and necessary information. From the point of view of maintenance, it is most effective to keep number of user groups as small as possible to minimize the time spent on managing the user groups.

From the point of view of security, general user accounts means numerically less weak passwords. On the other hand, the commonly used account and password is in wider use. Additionally, with general user accounts, in some cases, tracking the information misuse may be more challenging. To minimize this trade-off, it should be carefully considered whether the encrypted information in the system's databases is certainly necessary for the operation of the service. In addition, any database queries and changes that affect sensitive information should make the log entry in the system with timestamps.

9.4.1.1 Administrator

A user group which is able to solve the problem situations encountered by the other users. Typical problems are forgotten password or username. System should be designed so well that these problems should be minimized or they should be able to be solved by the user themselves without compromising with security. From security point of view, administrator level accounts are the most critical and should not be used unless the situation so requires. (Hovi 2017).

9.4.1.2 Supervisor ashore

Supervisor ashore is either general usage account or employee-specific account. Member of this account type has access to temperature sensitive cargo unit´s observations and customer´s contact information which is established via the backend system. The most important feature of this user group is the ability to build various statistics from the system.

9.4.1.3 Operator onboard

Onboard operator is either ship-specific or employee-specific account type. It is better for information security, employee legal protection and maintenance that the user account of this level is ship-specific. The user has limited access to the temperature sensitive cargo unit data only via handheld device by using the monitoring application. The user of this group is able to see the units to be loaded on board, temperature limit values and specific information regarding the unit including location information.

9.4.1.4 Supervisor onboard

Onboard supervisor is either ship-specific or employee-specific account type. For information security and maintenance it is better that the user account of this level is ship-specific. The user has access to the information of temperature sensitive cargo unit via a handheld device through the monitoring application and optionally via the backend system for voyage specific temperature observations. The user is able to access the customer´s contact information and the type information of the cargo.

9.4.1.5 Client user

Client user account is either client-specific or personal. The user is able to access to the temperature monitoring information and observations of his units in almost real-time and to the voyage specific information over a limited period. User is able to see markings of temperature observations, alarms, notifications to an emergency contact, and actions performed for the unit onboard.

9.5 Cost estimation

The price of the implementation of the system depends on how far the implementation is taken. Likewise, the benefits of the system will grow as more systems, users, or stakeholders join the implementation.

Without taking into account the workload and when utilizing the existing network infrastructure, Wi-Fi access points will have to add at least 2 pieces, one to the cargo office on cargo deck 3 and the other to the bridge. The first is used for data exchange with the backend system during loading and unloading and the latter used at the end of the monitoring round to store the collected data to the backend system. An optimum case contains four Wi-Fi access points on cargo deck 3, two access points on cargo deck 5 and two access points on cargo deck 7.

The system requires at least 2 pieces of handhelds. And in optimum case 5 pieces is required, one handheld for each cargo deck, one for supervisor and one as spare device. For practical reasons handheld devices should be durable and protected against moisture. According to writers observations, so called rugged tablets are generally much more expensive than rugged smartphones.

The cost estimation of the integration of backend systems and the development of new backend systems depends entirely on the scope of the implementation and where the collected data is intended to be stored. Whether own servers are to be selected, which maintenance costs must be taken into account, or rental servers, aka cloud service providers, which is making the costs easier manageable.

The pricing of the implementation of a monitoring application is also based on the complexity of the entity being developed.

There are different workload calculators on the Internet for evaluating the programming and developing costs. In addition, fixed-price package solutions are available for sale in order to cope with the most common use cases. In the end, however, all the development work on the individual case will require extra time and financial investments.

10 CONCLUSIONS

The choice of this topic was based on the author's own interests and experiences in the IT sector and on observations and experiences in the maritime sector. So the theoretical basis for the thesis has begun to accumulate for years before working in the maritime sector for current employer.

In the early stages of the thesis, this theoretical foundation that was already collected was structured and researched for up-to-date references. The writing process of the thesis was started on theoretical basis in summer 2017. The survey was conducted during the autumn and interviews were started between different parties. In addition to the interviews, interaction with the interviewees was maintained with active conversational connections.

Because of the periodic rhythm of maritime work, the thesis progressed in phases. Between the writing processes there were several one month long breaks which were got over by chopping the topic in smaller sections and by getting back to the topic over and over again.

This thesis studied how the monitoring of temperature sensitive cargo units is carried out on Finnlines' vessels, what problems are confronted in practice with current methods and how to improve them. For the thesis a survey was carried out for the vessels' personnel working with the temperature sensitive cargo units. The survey showed that almost all respondents felt the current methods somewhat clumsy and that the current methods could be improved. Most respondents are willing to test the possible new system, if it does not cause any extra effort. The challenges of digitalizing expected to be the battery life and the duration of the equipment in maritime conditions. In addition to the questionnaire, volunteers were interviewed to find out the problem areas and suggestions for improvement in the current methods and how to implement them.

The thesis studied the challenges of IT solutions in maritime conditions, such as moisture, wind, distances from the shore, and enclosed cargo spaces. The thesis pointed out on how Wi-Fi access points can be used to enable Internet connection to the cargo deck and how the Wi-Fi access points can be utilized in the user's location determination.

The thesis analyzed what information from existing backend systems could be utilized in digitalizing the method of temperature monitoring. For example, location information of cargo units from the stowage planning system could be utilized in cases involving inspections of individual cargo units. The booking information of the cargo units to be loaded onboard could also to be utilized for the system to be developed.

The description of the features of the monitoring application took into account the challenges encountered in the current monitoring methods and sought to find solutions to avoid or facilitate those challenges. The monitoring application should be easy to approach, user-friendly and intuitive. The handheld used for monitoring should be dirt, dust, moisture and shock resistant.

The benefits of the collected data may occur to unification of more efficient practices between the vessels and consequently overtime reduction, improvement in the exchange of information between vessels, office, and customers. Digitized data enables long-term monitoring and statistics and, where appropriate, creates opportunities for new service concepts.

10.1 The objectives of the study

The aim of the thesis was to find a way to streamline current practices in the monitoring of temperature cargo units by digitalizing them. In the thesis, one way to implement this was exemplified in general level. The goal was also to define the cost level for the digitalizing of such activity. However, the cost level is largely determined by the extent to which digitalizing is being implemented, and on the long-term perspective of this change. In addition, the quantitative magnitude of the estimated benefits varies for the same reasons.

10.2 Recommendations for future research

One topic for future research could be to determine the effects of digitalization costs in relation to the benefits that could be obtained. Additionally, the generality and interest of shippers' to trace their cargo units during sea voyage could be researched.

The maritime sector is considered to be very conservative when compared to other industries. Several discussions related to this thesis with the workers on Finnish maritime sector have shown that, despite the increase in general interest in digitalization, there are resistance to change in organizations, especially for suggestions and solutions introduced by members of the crew. In the context of the discussions, there have also been warnings and examples how some employers in maritime sector have been trying to exploit in morally questionable ways the innovative solutions which have come from their employees. Therefore one recommended topic for future research could be to study how companies in maritime sector, supports and encourages their workers for innovative solutions.

11 FINAL WORDS

The topicality of digitalization and positive reception of digitalizing the method of monitoring of temperature sensitive cargo units has led to the piloting phase of one system described in this thesis. Following months will show how far this system is going to be developed and integrated and what kind of enhancements and services it enables.

I would like to thank all the colleagues and co-workers for their actively shared feedback to this subject. Finally, I would like to thank my family for the support and patience that was requested during this thesis.

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Kysely lämpöyksiköiden monitoroinnin digitalisoinnista / Questionnaire for digitalizating the method of monitoring of the thermal units

Työskentelen laivalla / I am working on M/S ___________________________

Ympyröi haluamasi vaihtoehdot / Circulate your answers

1. Kuinka tehokkaana pidät nykyistä toimintatapaa monitoroida ELE-yksiköitä / How effective is the current method to monitor of thermal units?
    a. Tehokas ja helppokäyttöinen / Very effective and easy to use
    b. Parantamisen varaa on / Could be better
    c. Kömpelö ja tehoton / Stumble and ineffective
    d. Omin sanoin / free word

2. Mitä mieltä olet ELE-yksiköiden monitoroinnin digitalisoinnista / How do you feel about digitalizing the method of monitoring of thermal units?
    a. Viimeinkin / Should be done already
    b. Hyvä aihe mutta siinä voi tulla ongelmia / Sounds good but there might occur some problems
    c. Tietokoneet ovat paholaisen keksintö / Computers are evil
    d. Omin sanoin / free word

3. Haluaisitko olla mukana uuden järjestelmän käyttötestauksessa / Would you like to take part to the trial period of new system?
    a. Tottakai / Absolutely
    b. Jos siitä ei ole vaivaa / If it won't bother
    c. En missään tapauksessa / No! Never!
    d. Omin sanoin / free word

4. Haluatko jakaa omia kehitysideoita aiheesta / Would you like to share your own ideas about the subject?
    a. Kyllä / Yes
        i. by interview onboard
        ii. by email ______________________________
        iii. other method?
    b. Ei / No! Never!