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Author: Terje Rygh	.... (author signature)

Tutor: Prof. Jan Frick

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Alternatives for the Development of the maritime business in Rogaland

Written by:
Terje Rygh

Master's in Technology and Operations Management

University of Stavanger

Faculty of Science and Technology
University of Stavanger (UiS)
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Abstracts

The variance of ship arrivals and departures plays a major role in port and terminal operations. Variance creates unevenness, fluctuation and variation to the onshore supply- and value chain. The analysed SafeSeaNet Norway dataset contains arrival- and departure estimates from a 16-month period which shows that the actual time deviates considerably from the estimated times. There is a big potential to reduced costs when variance can be governed in a proper way mitigating the causes creating variance. Real time information sharing standards should be implemented in the supply- and value chain to enhance the quality of maritime services and customer satisfaction. By using the combination of Total Quality Management (TQM) and LEAN methods and tools, the maritime industry should be able to reduce the cost due to variation significantly. This includes the use of continuous improvement circle processes like the one of Kaizen to enhance resource utilisation. The study concludes that long term gains from mitigating and removing causes of variance will generate extra capacity and that changes can thus contribute to a new way of cargo transportation in North Jæren.

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Abbreviations

AIS:	Automatic Identification System
ATA:	Actual Time of Arrival
ATD:	Actual Time of Departure
EEA:	European Economic Area
ETA:	Estimated Time of Arrival/First
ETA_0:	The first registered Estimated Time of Arrival
ETD:	Estimated Time of Departure
ETD_0:	The first registered Estimated Time of Departure
IMO:	International Maritime Organization (IMO)
ISPS:	The International Ship and Port Facility Code (adopted by the International Maritime Organization (IMO) on 12 December 2002)
LO-LO	Load-On Load-Off (By crane or similar)
M2M:	Machine to Machine
RO-RO:	Roll-On Roll-Off (By trucks or similar)
SME:	Small and Medium-sized Enterprises
TOS:	Terminal Operating System
VTS	Vessel Traffic Service

1 Introduction

The author (Terje Rygh) has a Bachelor of Science from the University of Stavanger in "Business and information systems" (spring 2006) and has worked in the Port of Stavanger as IT responsible for the last 8 ½ years. Here he gained "hands-on" experience and an understanding of maritime operations and how software and m2m integrations can add value to the maritime industry. The author has in the last 3 ½ years studied a "experience-based Master degree in Technology and Operations management" and fully self-financed the whole master studies. During this period, the author of this paper has recognized how important it is to have the latest academic knowledge and to understand, learn and gain a better basis for preparing and building up organizations for the future challenges in the maritime industry. The authors rationale and goal in writing this master thesis has been in an objective way, to find new methods and tools for the maritime industry, by analysing the port calls and ship voyages coming to *Port of Sandnes.* He also hopes that this master thesis can lay grounds for further studies and discoveries which enable the development of new tools and methods for the continuous improvement of the maritime business and to help the Operations Managers in the maritime industry in reducing operational variance of own port and terminal operations. In short the author wants to contribute by investigating if "N*ew changes can help the maritime business to achieve better quality and reduce "waste" and thus enhance the customer value of their services?".* Working in the Port of Stavanger, the author wishes to keep the neutrality needed for doing good research by exploring and analysing the terminal arrival and departure variance of visiting ships in the terminal *Sandnes Havneterminal AS* in the *Port of Sandnes*. By looking into how the variance of ship arrivals and ship departures visiting ports and terminals, the effects variance has on terminal operations on the quay side can be observed and analysed. The goal is to see if the costs of variance for the maritime industry can be calculated and to see if there are any methodical improvements to be made. In looking at deviation time and calculating total deviation hours for ships in one port, one can assume that the same patterns and results applies for bigger regions like the North Jæren in Rogaland county or Rogaland county as a whole for similar ships, doing similar operations in similar ports and terminals.

1.1 The hypotheses (H1, H2)

To be able to formulate a hypothesis, we need to know what a hypothesis is. A hypothesis is defined as *"A supposition or explanation (theory) that is provisionally accepted in order to interpret certain events or phenomena, and to provide guidance for further investigation. A hypothesis may be proven correct or wrong, and must be capable of refutation. If it remains unrefuted by facts, it is said to be verified or corroborated."* (Business Dictionary, 2018b)

That a hypothesis is capable of refutation means *"[…] to say or prove that a person, statement, opinion, etc. is wrong or false […]"* (Cambridge Dictionary, 2018a)

A hypothesis is thus a claim that has been submitted and which can be verified or not verified. In addition, the findings presented must be reviewable by others. Meaning that others can do the same research and check if it is correct or false.

In the beginning leading up to these hypotheses there is only a very general idea of what they may be, or what we want to have higher observations and understandings about. It also needs to be something that not many or none has looked into. It may take a while before one land on a specific topic and can create a hypothesis. In the most cases one experiences that this process is not linear as one would hope for, and has many twists and turns. The way leading up to the thesis may have one or more iteration runs going the whole way up and down the research and data collection process (Iteration process 1, 2 and 3) shown in Figure 13 in chapter 3.3.1, before one is satisfied with the hypotheses.

After several iterations the following two hypotheses for this master thesis were presented:

H1: "New methods can make cargo transportation in North Jæren more profitable"

The first hypothesis (H1) looks at new methods for doing the infrastructure in the North Jæren able to be more profitable. In revealing the problems that maritime business struggles with there may be tools or methods that can improve the profit. By using the terminal *Sandnes Havneterminal AS* in the *Port of Sandnes* as a case, it might be possible to verify this hypothesis and draw the conclusion that this also apply to same or similar operating ports and terminals in Rogaland county and North Jæren region (Part of Rogaland).

H2: "Changes can contribute to new cargo transportation in North Jæren"

The second hypothesis (H2) looks at new changes both in technology and methods that can contribute to more or new goods being transported by sea. There may not be need for changes, to do nothing is also an available option. Or there may only be minor changes to existing methods and tools needed to have a new and "good enough" cargo transportation. By utilizing these better it should be possible to see if it has a positive impact on the maritime operations and its profitability.

Criticism

"In inductive inference, we go from the specific to the general. We make many observations, discern a pattern, make a generalization, and infer an explanation or a theory," Wassertheil-Smoller told Live Science. "In science, there is a constant interplay between inductive inference (based on observations) and deductive inference (based on theory), until we get closer and closer to the 'truth,' which we can only approach but not ascertain with complete certainty." (Bradford, 2017)

Analysing one terminal and the observations, does not allow the end logic to be that all other terminals or ports are similar. In using an inductive reasoning the conclusions goes from some observations, generalizing to all. *"Even if all of the premises are true in a statement, inductive reasoning allows for the conclusion to be false."* (Bradford, 2017)

It is therefore of utmost importance to do follow-up research. By just analysing the *Port of Sandnes* and its terminal *Sandnes Havneterminal AS*, there might be other results that refutes both these hypotheses. In this master thesis this is an important premise not to be forgotten. It has not been possible to gain alternative sources with same data as NCA has, and there are no other ports or terminals in North Jæren handling similar ships and cargo types having the needed and open data. At the same time the terminal in the *Port of Sandnes* has a unique location code (NOSAS) identifying them in a unique way. The two-way quay booking request/confirmation integration between SafeSeaNet and the ports and terminals is about to be implemented, if all goes well, in 2018. This would give the needed granulation, where it is possible to identify ships going to specific berths. This still do not make all companies/operators at the quays uniquely identifiable as there may be several operators using the same quays. For such operator analysis at shared berths there is a need for the data from the operators themselves containing data point history. Future studies can thus prove that the conclusions made in this master thesis is false.

Looking at all the data available the author has had to limit the scope, looking at and analysing all the ports in Rogaland is an impossible job for a master thesis written by one person. As a result, the author has chosen to study one port in detail and tried to draw some general knowledge from this analysis. The author has also concentrated the research around the important logistics of conventional cargo handling of goods such as food, industrial equipment, building materials, general cargo, luxury wares and so on to and from ro-ro and lo-lo ships. The *Port of Sandnes* meets the criteria of conventional cargo handling and is at the same time a port of a reasonable size and strategic location, it is also easily identifiable in the collected data.

The analysis starts out with a holistic view looking at the big picture of the Rogaland county, then we move on to the North Jæren region and end up with a closer look at the *Port of Sandnes* (Sandnes Havn KF).

The findings in the *Port of Sandnes* should act as the basis of new methods and tools that can be used to develop the maritime industry in a positive way by mitigating variance of arrivals or departures for similar terminals and ports in the whole of Rogaland county or the whole country of Norway (inductive method)[1]. By selecting a single port, the author thus assumes, using an inductive method, that the findings in one port is representative for terminal doing similar operations as.

1.2 Aims and objectives

As later described in chapter 1.4.2 the port has chosen to give their customers fixed costs without concern of variance, so that the customer does not get any surprises when arriving late or early. In one of the telephone interviews made with employees at *Sandnes Havneterminal AS*, the terminal in the *Port of Sandnes*, said *"The Port of Sandnes is a low cost port"*. The author can confirm this when he looks at some of the other actors in North Jæren. The author finds that if the cost cannot be allocated to the actor causing variance, new methods and tools are going to be even more important to implement. The main aim of the author is to analyse what effects and costs deviation of arriving ships have. And even a "low cost port" is affected by operational variance in one way or another. It is very important to focusing on mitigating deviance to lower own costs. We need to govern variance in own

[1] See definition of "Inductive method", in chapter 1.7 Terms and definitions

organizations but other stakeholder's organizations are also important to inform and discuss in which ways we in common can mitigate this.

By doing a ship arrival and departure analysis of the *Port of Sandnes* it should be possible to derive some common results that can be used, in analysing and improving operations in ports and terminals. If we know how many hours before or after the planned time of arrival the ships actually arrive the terminals, we can calculate how much the total deviation time costs the terminal and port. The variation calculated is the variance of early or late arrival to the berth and the late or early departure.

Because the transport of conventional cargo is so important, knowledge gained from the *Port of Sandnes* could be used for the rest of the maritime industry, hopefully improving operations in similar ports and terminals. We also want to see if updating voyage data more often can reduce the deviations to port and terminal arrivals and departures. Lessons learned from this maritime sector may apply in others as well.

Because of limited resources and time constraint the author has not had time to research and analyse the rest of the downstream value chain from the truck drivers picking up or delivering cargo at the terminal and down till the customer and end consumer. Hopefully this work can be continued in other studies.

1.3 Background

"Water connects and mountains divide" - goods traffic has been traveling by sea from the time the humans managed to build rafts and smaller ships many thousand years ago. The shipping industry has over time grown and plays a huge role in transporting gods to customers and end users. To get an impression of what the present maritime business in Rogaland looks like, we need to look at the "conditions" the maritime business is operating under at present time. This master thesis explores the present and future methods for the maritime business in the county of Rogaland and in the North Jæren region in Norway. To find new methods we need to first find the problems and make them visible as the first step in the Lean-tool "Kaizen" describes. Let's start by taking a holistic view at the present situation for the maritime business in Rogaland.

1.3.1 The present maritime situation in Rogaland

Rogaland county has a strategical maritime and economic location in the southwest of Norway, and it is one of the 13 counties in Norway. In 2016 the Stavanger region (North Jæren) in Rogaland County dropped one place on the regional maritime economies list and is now "*the third biggest maritime region in Norway, surpassed by the Oslo fjord and Bergen region which now rank first and second*" Fride Solbakken (CEO, Maritimt Forum for the Stavanger region) told in one of the interviews made for this master thesis.

The latest report from Maritimt Forum, which is to be released in the near future describes this in the figure Figure 1 below taken from the report written by C. Melbye, E. Jackobsen, Menon (2018).

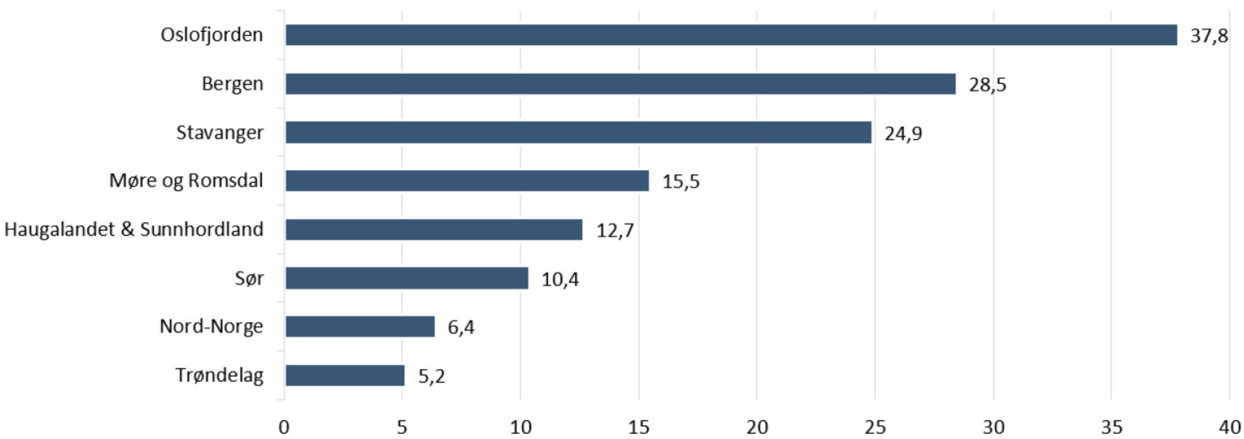


Figure 1 Regional Maritime value creation (in Norwegian kroner NOK) (Melbye et al., 2018)

Being the third biggest maritime region means that we can assume that improvements made here can contribute to better Just-In-Time (JIT) operations in the other regions either by direct improvements or indirect as a part of an improved value and supply chain.

For the last four decades the maritime sector in the Rogaland region has had a very high focus on serving the oil service and oil production industry. This in turn has a cascading effect, creating vertical and horizontal offshore and onshore jobs in this maritime area.

1.3.2 Falling oil prices and the maritime industries dependency on the oil market

The one-sided focus on serving the oil production and oil industry has made large parts of the business in the maritime and offshore industries highly exposed to the oil cycle, and is currently under strong criticism due to that dependency. Today the maritime industry and other oil dependent businesses and industries are looking to mitigate the exposure to the oil sector and tries to find and develop new areas outside this arena. After the rapid fall of the oil price experienced in 2014 and 2015 the maritime industries had to go through bigger changes.

In mid-2014 the international oil business was struck with a fall in the oil prices which also struck the Norwegian oil business in Rogaland hard. The value of Crude Oil Brent Spar fell sharply from around $110/brl to under $60/brl within 7 months, and then to plummeted to under $40/brl in late 2015 as seen in Figure 2. At the moment (spring 2018) the oil price has risen to around $65/brl.

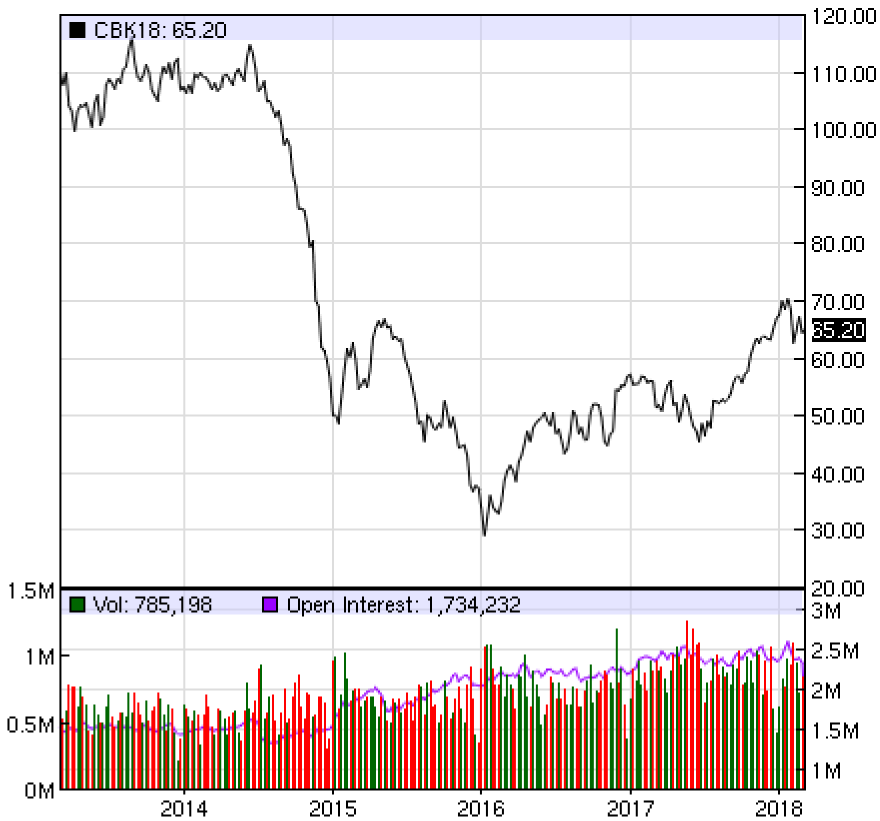


Figure 2 End of day Commodity Futures Price Quotes for Crude Oil Brent March 2013- March 2018 (Nasdaq, 2018)

Four years after the fall, there is still a negative sentiment in the oil related businesses in Rogaland which affects the whole oil sector in an undesirable way and has spread to other areas of the country. This change was not immediately recognizable and it took the offshore industry some time to recognize this. Soon after the fall was recognizable, major oil companies like Statoil stopped projects and started to cut costs. Supplier contracts can range from days and months up to years and the they may have multiple contracts with a mix of these ranges and cancelling contract takes some time to take effect. Therefore, many companies and subcontractors experienced the full effect much later and often first after projects stopped. This in turn hit oil supply industry and the maritime industry hard and forced them to lay off people. Many of the maritime jobs in Rogaland are still correlated to the oil price and things seems to go in the right direction again, but the uncertainty is still felt. In addition, the oil sector fears that they will get problems to find qualified employees when hiring again due to a lot of people looking for jobs in other sectors and businesses.

The figure below shows this delay effect for the offshore ships. The figures are registered by SSB (The Norwegian Statistical Bureau) from the three major maritime offshore areas in Rogaland (Stavanger, Karmsund, Egersund). It shows a graph derived from SSB data of the Offshore Port Calls (port calls per quarter year) in Rogaland.

Before the third quarter of 2015 (2015Q3) the Offshore segment shows a stable level variating between 800 and 900 vessels per quarter. This dip may have been caused by a lack of registrations from the reporting authorities, seasonal variation, or high activities elsewhere causing ships not to visit, these are mere speculations and should be investigated by the appropriate statistical authorities. After the 4th Quarter of 2015 we can recognize a negative change. From a peak of 904 (2015Q4) it drops to 710 (2016Q1) port calls from one quarter to the next, before having a "double dip" down to 597. This is a reduction of 307 offshore ship visits. In percent this drop was a negative 33,96 %, which is a considerable drop from the 2013-15 level.

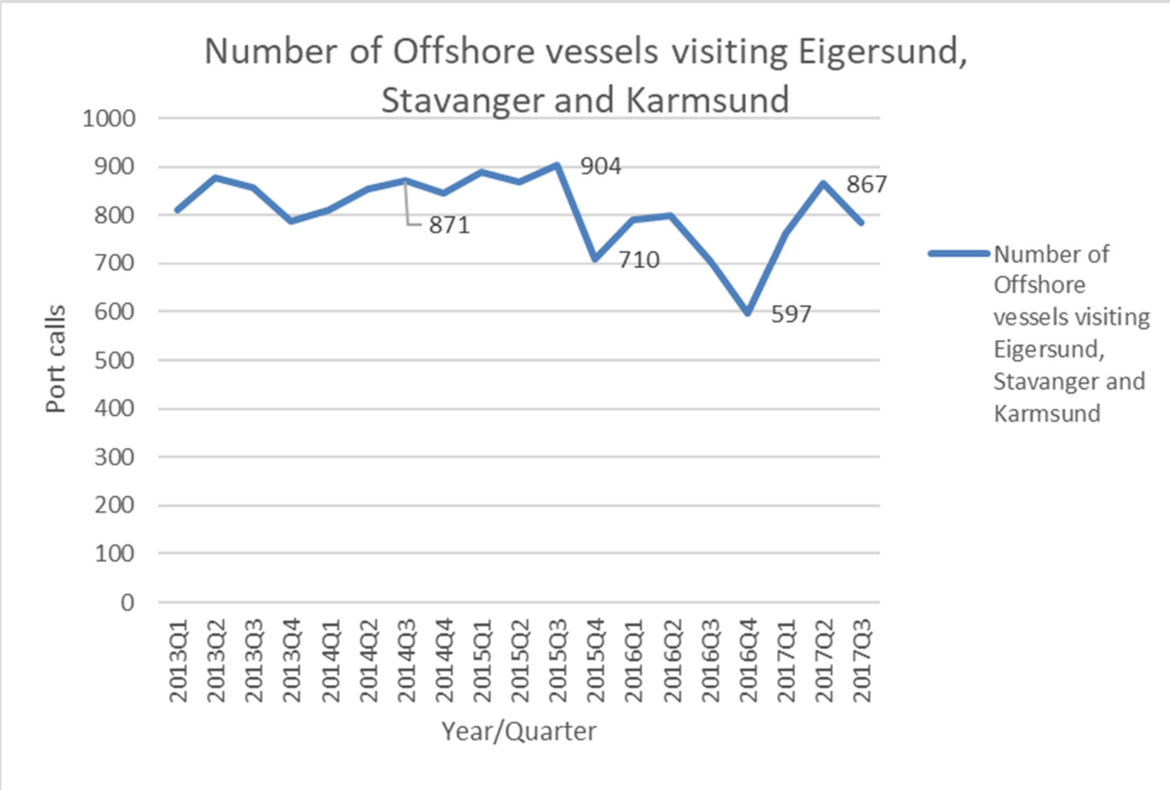


Figure 3 Offshore ship reduction and delayed effect of lower activity (SSB, 2016)

The effect of this was that in July 2017, 6% of the working force in Rogaland were either unemployed, partly unemployed or attending labour market measures. (NAV, 2017). And the effect is still felt in the North Jæren region.

1.3.3 The situation for the other maritime areas

The region has historically grown its maritime riches from the North Sea and the shipping lines crossing the area. The region offers a multitude of services connected to local, national and international maritime business areas exporting and importing goods. The region exports local products like fish, gravel and stone, and imports industrial equipment and food. There is also a relatively good inland connection from most terminals for further transport by road, even though urban areas can have "digestive" rush hour and there are some local road problems.

The other maritime sectors can be seen as the "back bone" of the maritime activity in Rogaland. Even if the oil business has taken much "space" the last decades, these other maritime sectors have survived and made money serving other import/export industries and by bringing the population much needed import food, luxury goods and other articles even with much lower operating margins than in the oil business.

Looking at the whole picture we see that all of the maritime industry including the oil industry needs to look at their operation management and the governance of variance. Many observers have raised their voices arguing for a more balanced industry, not dependent on just one business sector (The oil market and oil prices). This is one of the reasons why the author has chosen to look into the "conventional" maritime cargo industry and analysing the *Port of Sandnes* (Sandnes Havn KF) in particular who themselves state the following: *"The strategy for port operations in Sandnes is to build, maintain and operate efficient and rational"* for *"[…] lift on / lift off […]"* and *"ro-ro traffic, bulk loads and conventional general cargo traffic. In addition, a limited amount of container traffic is arranged."* [translated from Norwegian] (Port of Sandnes, 2017)

In general, the none-oil maritime industry has felt the impact of the fall in the oil price but the weaker Norwegian currency (Norwegian Krone, NOK) has contributed to growth in other export industries and thus the maritime sector outside the maritime oil business has in general been able to in different withstand the fall.

1.4 SafeSeaNet

The "National Single Window", SafeSeaNet, is a *"[...] European Platform for vessel traffic monitoring and information exchange between […] maritime authorities established in order to enhance maritime safety, port and maritime security, marine environment protection and the efficiency of maritime traffic and maritime transport. [...]"* (MVV decon and Tractebel Engineering GDF Suez, 2013) It was created as a result of having two major maritime accidents where the ships Erika (1999) and the Prestige (2002) caused major pollution and negative environmental impact.

The two accidents were two out of *"A number of major accidents[which] have occurred over recent years around European Union coasts, raising questions regarding the accuracy and the level of information in* ***dangerous and polluting goods*** *(HAZMAT) reports." (EMSA, 2017)*

These accidents paved the way for the creation of EMSA (European Maritime Safety Agency) and the creation of a “National Single Window” called SafeSeaNet in each EEA member state.

EMSA is *“[…] one of the EU's decentralised agencies. Based in Lisbon, the Agency provides technical assistance and support to the European Commission and Member States in the development and implementation of EU legislation on maritime safety, pollution by ships and maritime security.”* (EMSA, 2018)

The “National Single Window” in Norway is administrated and owned by Kystverket (The Norwegian Costal Administration). SafeSeaNet in all EEA member states collect different arrival and departure data from ships entering the VTS areas, which in turn are used by other stakeholders. These stakeholders may be different in different countries. In Norway the stake holders are listed below in chapter 1.4.2 below.

1.4.1 The Norwegian Costal Administration (NCA)

"The Norwegian Coastal Administration is an agency of the Norwegian Ministry of Transport and Communications responsible for services related to maritime safety, maritime infrastructure, transport planning and efficiency, and emergency response to acute pollution." (Kystverket (NCA), 2018)

The Norwegian Costal administration is the national authority that owns and governs the SafeSeaNet Norway (SSN-N)

1.4.2 SafeSeaNet Norway (SSN-N)

In Norway the “National single Window” is called SafeSeaNet Norway (SSN-N). The NCA owns, and operates the SSN-N.

"SafeSeaNet Norway is an internet based reporting system that makes it easier and faster for ships to send electronic notifications to Norwegian authorities. The reporting system collects regulated infor-mation from shipping, and ensures that this information is made digitally available for relevant government agencies."[translated from Norwegian] (Kystverket (NCA), 2014)

The function of SSN-N is to be a “one way in, and many ways out system” (One ship to many authorities/stakeholders). The NCA develops this system in cooperation with all the maritime actors and other Norwegian and international authorities.

In 2004 the first SafeSeaNet "emerged", as a result of this. In the same year, the Norwegian version SafeSeaNet Norway (v. 1.0) "saw its first light". This first version was mainly focusing on the Arrival/Departure/Hazmat messages that the ships had to report to the central authority (Kystverket/Fiskeridepartementet). In later versions the focus has been Maritime Stakeholders (v. 2.0) and Single Window for Authorities and Trade (v. 3.0) (Hauge, 2016)

The background and ambition of the SafeSeaNet - "Single Window" is to follow the "National & regional legislation", "Simplify ship reporting" and get a better "Emergency preparedness", "Enhance[d] safety and security" and to "Facilitate trade". (Hauge, 2016)

It is the collected data from the National Single Window in Norway (SafeSeaNet Norway), that is the basis for the empirical part of the study in this master thesis.

1.4.3 SSN-N Stakeholders

The stakeholders can be divided into three groups. *(1)* The first group consists of NGO’s and other public actors concerned about safe and sustainable ship traffic. *(2)* The second group consists of the data providers, who register data in SSN-N. This group mainly consists of the ships who have to report into the National Single Window, but some ships have an agent or the shipping company acts as an agent (only Norwegian ships). The ships, ship owners and agents uses SSN-N on a daily basis to fulfil their mandatory duty to report in their voyages in the “National single window”. *(3)* The third group consists of NCA themselves, the Police (Border Control), the Army/Navy (National security), The Customs, The Ports (Port authorities, Public- or Private ISPS terminals) and The Ministry of Transport and Communications.

1.4.4 Mandatory reporting

Not all ships have to report in their voyages in SafeSeaNet Norway and are exempted, like ferries in local traffic going to and from non ISPS terminals. The ships that do have to mandatory report into SSN are mentioned in the ***"Regulation on vessels' notification obligations under the Harbour and Fairways Act"***. In short summarized as:

- Ships who are visiting ISPS-terminals and *"[...] in international traffic shall provide the port facility with information [...]"*
- *"Vessels with a gross tonnage of 1,000 or above, and which have bunker or lubricating oil for use on board, are considered to be a vessel that carries hazardous or polluting cargo [...] that depart from a quay, anchorage or mooring facilities in Norwegian territorial waters shall, prior to departure, provide information about the time of departure from the port and the expected time of arrival at the port of destination."*

There may be given exempt from the notification requirements if they fulfil some requirements.

"Unless otherwise stated in the regulations, the vessel shall notify [...] a) At least 24 hours before arrival at the port of destination, b) At the latest when the vessel departs from the previous port, if the journey is less than 24 hours or c) As soon as the port of arrival is known." (2017, Kystverket)

"The master of the vessel is responsible for ensuring that notifications [...] are submitted and that the information is updated.". Others (E.g. Agents, Ship owners) can report in the notification on behalf of the master, but it is in the end the master who has the responsibility that it has been done and done correctly. (Vardø Vessel Traffic Centre, 2015)

1.5 The Port of Sandnes / Sandnes Havneterminal AS, Norway

The *Port of Sandnes* (Sandnes Havn) is a public owned port, situated at the end of Gandsfjorden in Rogaland County. The port has around 600 port calls yearly, visited mainly by general cargo ships doing discharging and/or loading of ***conventional general cargo traffic*** going to and from the port. The port is the parent company of the terminal company called *Sandnes Havneterminal AS* owning 100% of the terminal. The port has been chosen as a case as its terminal *Sandnes Havneterminal AS* primarily handles ***conventional general cargo traffic*** and is thus ***a clean case*** for the master thesis analysis of this kind of traffic and can be representative for this cargo traffic in all of Rogaland.

In 2017 the terminal’s parent company (The *Port of Sandnes*) had 3 full time employees, in the terminal company there were 13 full time employees. The port had 655 port calls and 669 berth visits (14 ships shifted berths) in 2017. In the further text when referring to the *Port of Sandnes* the author means the entity of the both mentioned companies, unless stated otherwise.

The goal of the *Port of Sandnes* is that it *“[…] will be an attractive, eco-friendly and efficient logistics hub for business and industry in Sandnes and Jæren, for the benefit of its citizens and society. Customer needs will be the guiding principle for our services!”* [translated from Norwegian] (Port of Sandnes, 2017).

The cargo handled at the logistic hub (terminal) comprises of everything from palletized cargo, to bulk, to steel pipes and containers which is going over around 900 meters of quay, using cranes and fork lifts for accommodating ships in loading and discharging operations. The Port is also strategically placed with short distances to the rest of the Jæren region and has short ways to other modal solutions.

The main users of the *Port of Sandnes* are *“[…] shipping lines, vessels operating in short term markets, shipping agents, dispatchers [logistics companies], importers and exporters […]”* [translated from Norwegian]. (Port of Sandnes, 2018b)

In 2017 they experienced a reduction of 8% in the cargo handled compared to the year before. In 2017 they had a total of 214 114 ton transported and handled over their public quays. The Port’s own explanation for the decrease is that *“Traditional general cargo has decreased and the reason is presumed to be reduction in the oil business and a harder competition from heavy vehicle traffic by road.”* [translated from Norwegian] (Port of Sandnes, 2018b) The case is described in more details later in chapter 4.6.5 below.

1.6 Rationale

For most industries the variance in the supply or value chain will cause difficulties. The maritime business is known to be a conservative area, but is at the same time an industry dependent on good logistic solutions. Ports and terminals experience variance from ship arrivals and from hinterland integrations. The supply and value chain downstream is not a part of the study where we only look at the upstream variations caused by the ships arrivals and departures to the terminals and ports. Future maritime managers need to know how much such variance affects the terminal operations. Can investments in new methods and tools help, and how can using IT in collecting and interpreting data help? The present IT systems may already have many useful features, but the systems may not be collaborating and collecting enough relevant data between the stakeholders. Having the right data is not useful if there is no usage of it. Having too little or too much data/information is also not wished for the situation. Analytical IT tools are going to be more and more important in the future and the need for managing "big data" increases. The maritime business should increase their knowledge of how to use this data correctly and how much it is worth to invest in. The data needs to be analysed and interpreted before we can use it. In a data driven world it is going to be crucial to manage these data to "stay on top" of the evolution and to fully govern the existing and new ways of doing maritime business.

In having a standardised approach looking at the data in the same way, relevant data and results should be reusable for stakeholders within the same or different areas of the maritime industry area or cluster. In knowing what data to share or collect, gives a basis for analysis and may contains useful information that give value. The stakeholders who needs to interact, will then have a common collaborative understanding of the data which in turn is paving the ground to achieve good operational results. If found, new tools and methods may open a new way for terminals and ports by giving them the means to uphold a best practice by better following up on "production" deviations, in a continuous way, mitigating the negative effects on operations and JIT delivery. By sharing own data to relevant partners the whole value chain and in turn the whole maritime cluster could be more effective and cost saving way by mitigating unwanted waste (Muda). Different actors and stakeholders needs to know what is important for them to operate at their best at their operational level, information sharing is also crucial in the whole value and supply chain. For the management, a report showing weekly or monthly data reports and predefined Key Performance Indicators (KPI's) may be enough. For the employee or lower level managers there may be a need for more detailed information in “real time” and in a frequent manner, to do their tasks optimally at their level of operations.

In the future actors and stakeholders in the maritime business will be more and more dependent on secure and trustworthy information. The upholding and securing of IT infrastructure will be more and more important as the industry will get more and more information driven. It is therefore crucial to have redundant solutions where needed and sufficient IT security as well as backup and emergency plans for the cases where critical systems stops to work (fails). The maritime business also needs to invest in training their employees, most jobs are going to demand more from the employees and we need to prepare in training the existing working force and recruit the right personnel for the future. The goal of this master thesis is to analyse the present situation, show the findings and hopefully give present manager and future studies new tools and methods as well as an idea of where and what to look into.

1.7 Terms and definitions

Term	Definition
Δh (ETA-ATA)	The time difference between Estimated Time of Arrival (ETA) and Actual Time of Arrival (ATA) in hours (h).
Δh (ETD-ATD)	The time difference between Estimated Time of Departure (ETD) and Actual Time of Departure (ATD) in hours (h).
Berth shift	Ships moving between two or more quays during the same port call (port visit)
Break Bulk Cargo	Goods that must be loaded individually, and not in intermodal containers nor in bulk
Deductive method	The reasoning of a deductive method reasons from all to some observations. E.g. *"All men are mortal. Harold is a man. Therefore, Harold is mortal. […] In deductive reasoning, if something is true of a class of things in general, it is also true for all members of that class." (Bradford, 2017)* "For deductive reasoning to be sound, the hypothesis must be correct." (Bradford, 2017)
Inductive method	The specific observations are used to makes broad generalizations and conclusions (from some to all argumentation). E.g. ***'The coin I pulled from the bag is a penny. That coin is a penny. A third coin from the bag is a penny. Therefore, all the coins in the bag are pennies.'*** (Bradford, 2017) This method of arguing contains uncertainty about the results as *"[…] we can only approach but not acertain with complete certainty.*" (Bradford, 2017)
Just in Time (JIT)	In JIT manufacturing of goods and services the goal is to deliver the right product at the right place, delivered just in time, serving the needs (of goods or services) at the exact time of delivery.
Mean	"The "mean" is the "average" […], where you add up all the numbers and then divide by the number of numbers."(Stapel, 2017)
Median	"The "median" is the "middle" value in the list of numbers. To find the median, your numbers have to be listed in numerical order from smallest to largest, […]" and we "[…] may have to rewrite […]" the "[…] list before […]" we can find the median. (Stapel, 2017)
Mode	"The "mode" is the value that occurs most often. If no number in the list is repeated, then there is no mode for the list." (Stapel, 2017)

MUDA	Eliminate waste (One of the Lean manufacturing key objectives) (Formaspace, 2017)
MURI	Ensure efficiency by avoiding overburden (One of the Lean manufacturing key objectives) (Formaspace, 2017)
MURA	Ensure efficiency by avoiding uneven workloads (One of the Lean manufacturing key objectives) (Formaspace, 2017)
Pilot	A "Pilot" also called "Maritime pilot" or "Marine pilot", is a *"[…] sailor who maneuvers ships through dangerous or congested waters, such as harbors or river mouths […]"* and is the *"[…] navigational expert for the port of call."* (Wikipedia, 2008)
VoyageID	A voyage ID is a unique number given for each voyage registered in SafeSeaNet Norway (SSN-N). The ID is created by the first registration of a new ship voyage arrival when a ship registers its first Estimated Time of Arrival (ETA_0) for the next port. This first registration (and VoyageID may also contains the first Estimated Time of Departure ($ETD_{0)}$.

Table 1 Terms and definitions

1.8 Presumptions and assumptions, limitations and constraints

One of the steps in this master thesis is to verify variance and to estimate the total size and amount (in hours) as well as doing an estimate of man hour-cost and try to calculate how much this cost amount to on a local level (Sandnes Havneterminal AS) and for the North Jæren area and Rogaland County using SafeSeaNet-Norway's ship arrival and departure data.

During the data analysis the author has encountered some limitations and constraints using the given datasets. This should be taken into account as this affects the analysis, the precision and quality of the analytical results. The author listed up all the limitations, constraints and relevant presumptions and assumptions made, below.

1) The maritime business is a very competitive arena and the author's has no desire to have a restricted access on this paper that prevents the master's thesis from being published. This has limited the retrieval of certain data, such as payroll information and other direct or indirect operating costs, as well as other from Terminal Operating Systems (TOS) or Port Management Systems (PMS) that the enterprises or employees deem confidential.
2) The collected data contains much data not analysed, due to time constraint and the impossible task it would be to analyse all ports and terminals in Rogaland at the same time conducting interviews and complete this in a master's thesis in due time. The author had the big goal of looking at the data of pilot bookings and to look at if arrival at certain week days or holidays like would have different variance, but has chosen not to due to the same time constraints.

3) The data used in the analysis contains seasonal and auxiliary ships which do not discharge or loads conventional cargo, and is thus is not operating in the same way. These ship types have been filtered away before the specific analysis of the *Port of Sandnes*. The ship types are filtered away from the data given for the *Port of Sandnes, North Jæren and Rogaland*: Crew Boat, Cruise ship, Passenger Ferry, Tug and Yacht.

4) Ports with other operational patterns may have other findings (E.g. ports with seasonal or other operations than those found in the *Port of Sandnes*). There may be other results coming due to different levels of operational criticality, seasonal variance and frequency. As well as them serving other ship purposes and ship types than those found in the *Port of Sandnes*. E.g. a person interviewed in the *Port of Sandnes* stated that there was not a big problem of ship visits coming into conflict with each other as most of the ships were in regular or near regular

routes, the other ones coming sporadically were manageable. This "lack of" quay booking problems, may be constraints or bottleneck that other terminals and ports in the "holistic" analysis of North Jæren or Rogaland, have. In using the *Port of Sandnes* there may be ports and terminals experiencing more system "stressing" and ship variations. This increases the uncertainties of this study.

5a) To calculate a deviation from an estimated arrival or departure we also need an actual time to do calculations. Without the "Estimates" and "Actuals" we cannot calculate the time difference between Estimated time of Arrival (ETA) and Actual Time of Arrival (ATA) or the Estimated Time of Departure (ETD) and the Actual Time of Departure (ATD). It will be impossible to calculate any deviation (Δh) of an arrival or departure in any other way than using the formula $\Delta h_{arrival}$ = ETA-ATA for the arrival messages and the formula $\Delta h_{departure}$ = ETD-ATD for the departure message.

5b) The users of SafeSeaNet Norway (SSN-N) do not always need to register or need to update all values like "Estimates" or "Actuals" on the SSN-N web site (www.shiprep.no) before they are allowed to save their "digital voyage". Therefore, not all of the SafeSeaNet Norway (SSN-N) received from the Norwegian Costal Administration (NCA) have the needed "time stamps" with "Estimates" (ETA/ETD) and/or the corresponding "Actuals" (ATA/ATD) needed to calculate variance of arriving or departing ships. In addition, SSN-N did not start the automatically actuals registering of the ships AIS signals (Automatic Identification System) until the middle of June 2016. In the system it is not compulsory to manually report and save "Actuals". The "From/to" destinations of the voyages are also missing for a great number of registrations. Therefore, many of the registrations cannot be used, lacking either the information about voyage destination or the needed "time stamps".

5c) Out of the total 46 months of data given (1st of January 2014 till 24th of October 2017), the total NCA data set only contains AIS registrations (Actuals) for the last 16 months of data. We thus only have Actuals for the period of 16th of June 2016 till the 13th October 2017. This limits the amount of voyage data to about ¼ of what it could have been and what the intention was when collecting the data.

6) The final analysis looks at the SSN-N reports from 24 last hours' prior of ship arrivals. According to the retired Ship agent Thor Egil Slettebø, also confirmed by Dag Matre (Maritime Coordinator at the Port of Stavanger), most terminals and ports have a good opportunity to manage ship deviations occurring earlier than 24 hours before the planned time

of arrival. This gives an indication that we should look at the reports from the last 24 hours prior to the arrival, to see if more updates will contribute to better Just-In-Time (JIT) arrivals and the ports cargo operations. By calculating the total hours of deviation a test of the hypothesis "updating voyages often will give better predictions and JIT operations".

By limiting the analyse to these last 24 hours before arrival, we may exclude valid data and thus increase the uncertainty. Ships may only report arrivals and departures once. If there are any reports and updates done before the last 24 hours prior to the arrival or departure, these data will not be included in the analysis. We need to be aware of this when limiting the analysis to these last 24 hours' analyses. At the same time, we do not take in account the humans aboard the ships themselves, where human factors may play a big role. Since reporting in SSN-N is compulsory, almost all ships or agents register as they are supposed to do, but due to the fact that updating old values are not compulsory when things changes, new estimates may not be reported in SSN-N for different reasons. This is supported by the fact that the mode for the all ships travelling to terminals and ports in Rogaland the update Mode[2] is 1, meaning that most ships only register once (1st registration) and later never update their SSN-N arrival messages. The ships who only report once, may do so at latest possible time because they then have a more precise knowledge and do not need to update several times and thus saves time on reporting and updating compulsory reports. This in turn influences the result and uncertainties around when and how often updates are coming. There are a couple of things we need to be aware of that may occur and which would limit the precision and confidence of the study knowing the above things. A ship which seems to have a "bad record" of predicting its own arrival may only have reported once in SSN-N at very early time and for different reasons it never updates its voyage estimates again, may have informed the port at a later stage. This is not picked up using only the SSN-N data, and should be looked at in future studies. The same ship will then not affect the result in a negative way as it should have done if the data was registered earlier than the 24-hour limit set and never updated through other channels. A ship which seems to "be good" at predicting its arrivals by doing many updates of its "Estimates", may be perceived as "good" because they are reporting many times during the last part of its voyage (arrival) or berth stay (departure) and thus show a positive trend closing the gap between the estimated time of arrival and the actual time of arrival for each update. But even by having good intentions it may unwillingly be "messing things more up" because

[2] The definition of "Mode" can be found in chapter 1.7 Terms and definitions

the estimates vary at a very late stage of their voyage or berth stay. This is the time when we really do not want this noise “stressing” the system, and only big deviations should be reported. Without knowing the individual ships reporting “tactics” it is chosen to accept the uncertainties arriving from such a 24-hour method. Knowing that not having the knowledge of “human factors” at all given times, and that a ship updating 96 hours in advance is not as critical at a ship updating their estimates within 24 hours of arrival, and how these factors may affect the statistics and most certainly gives a different outcome than what is actually the case, it should still give us a general idea of what happens when ships update often and what the total amount of arrival and departure deviations may sum up to, using the reports coming from the 24 last hours before a ships arrival or departure.

7) The “Notification Time”-timeline is calculated different for departure voyages. It is set to looking at the first departure notifications (ETD_0) made in the arrival messages 42 hours prior to the actual time of departure (ATD). The 42 hours are calculated from the fact that the average berth stay is of 18.2 hours in length, added with the observations 24 hours before the actual time of arrival (ATA). In this way most of the first estimated time of arrival (ETA_0) and the first estimated time of departure (ETD_0) can be looked upon together from the same arrival message. As stated for the arrival notifications described in 6) above, the same counts for the departure analysis, by limiting the analyse to observations made the last 42 hours before departure, we may exclude valid data and thus increase the uncertainty. Ships may only report departures once. If there are any reports and updates done before the last 42 hours prior to the arrival or departure, these data will not be included in the analysis. Using an average could exclude a substantial amount of departure observations.

8) The way AIS generates “Actuals” (like ATA and ATD) for SSN-N registrations may have some influence on the quality of these data. The signal “offset”, up-time and port and terminal locations (coordinates in a map) may increase the uncertainties to whether the ship was actually laying at berth when registered. The actuals registered in SSN-N are registered when a ship is laying still, the signal it in turn connected to the closest “dot” in an electronic map. Knowing that AIS-Norge which the costal administration uses these points in a map marking a port and terminals, the ship may lay quite far from the quay for anchor or still for other reasons and still be registered as laying at quay. This increases the uncertainties of the SSN-N actual data, and thus the estimates of deviation. This is of importance when looking at the whole of Rogaland county, buy should only affect the study of the *Port of Sandnes* minimal as

the port lies in the end of a Fjord and most ships go alongside to the quay and do not wait or stop before arriving at berth.

9) The usage of the National Single Window may differ from ships to ship and port to ports. Some ports like the Port of Stavanger have gone out and said that the only way of reporting ship arrivals are through the National Single Window (SafeSeaNet Norge). This means that ships who wants to visit or book a public terminal must request this through the “single window” before they can come. In reality this means that agents or ships first contact the port via mail or telephone and first request a timeslot through the “single window” either shortly after they have talked to the port on phone, or just before when they take this call. This is similar for Sandnes Havneterminal AS and thus The *Port of Sandnes*, bookings are mostly reported in SSN-N after they have contacted the terminal. The time between the time of contact to the terminal/port by email or telephone and the time the reports of estimates (ETA/ETD) and the actual time of arrival or departure (ATA/ATD) have not been looked into in this master thesis but may have influence on the results and adds uncertainty. Future studies may have the possibility to do so.

2 Theory

Variations caused by late or early ship arrivals at terminals and ports in the maritime sector, affects the whole downstream supply- and value chain as cargo can only be moved from or to new destinations when the ships are there.

"The difference between a value chain and a supply chain is that a supply chain is the process of all parties involved in fulfilling a customer request, while a value chain is a set of interrelated activities a company uses to create a competitive advantage." (Tarver, 2018)

Much variation, fluctuation and unevenness (**Mura**) is unwanted from the customer and end user perspective. Big changes of the supply of goods or services from the supply chain affects the sequential operations in the value chain, impacting the quality of goods or services.

Based on the impact variation has to the quality of services that ports and terminals offer, and the importance of these services for the rest of the value chain, two main theories are discussed and used in this master thesis, namely the theory Total Quality Management and Lean methods and tools. They both look at the quality and waste in a supply and value chain and how to improve the quality by mitigating or removing waste.

"The lean concept is slightly different from TQM and six sigma. However, there is a lot to gain if organisations are able to combine these three concepts, as they are complementary. Six sigma and lean are excellent road-maps, which could be used one by one or combined, together with the values in TQM." (Andersson et al., 2006)

Both theories are high focused on how to increase the customer value of products or services by using tools and methods for *quality* improvements and waste reduction (Mura, Muda, Muri).

Below follows a review of the literature and theories which has shaped the end product in this master thesis. Please note that the tools and methods listed, are partially used in the master thesis as many of these are not applicable for all situations meet in the case(s) or topics that the master thesis introduce.

2.1 The productivity challenge

In Figure 4 below we see what is called "The productivity Challenge". *"Productivity is the ratio of which outputs (goods and services) divided by one or more inputs (such as labour, capital or management)"* (Heizer and Render, 2014) The productivity challenge lies in using as little input as possible to create the most output. Improvements can be done in either (1) reduce the inputs and still have a constant output or (2) increase the outputs and still have a constant input.

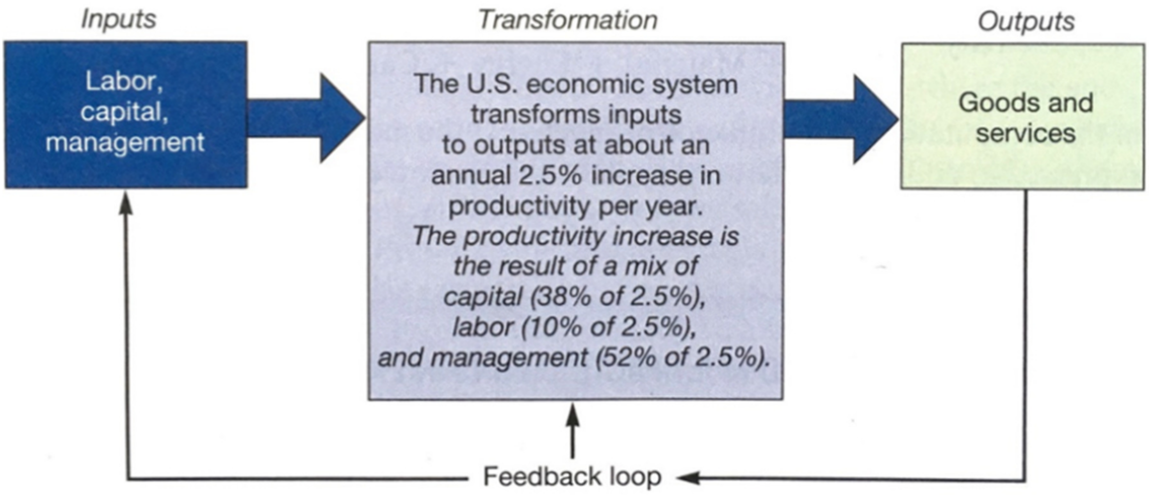


Figure 4The Economic Systems Adds Value by Transforming Inputs to Outputs (Heizer and Render, 2014)

Most ports are producing output of services which has the same challenge as seen above and the two ways of improvement. The difference in output of services to output of goods are that the quality of services may be difficult to determine due to the intangible nature of services. A good waiter in a restaurant that pays attention to the customer will most likely give the restaurant a better reputation and get more in tip (better revenue and sales) than a waiter at the same restaurant not paying attention, even if the tangible product (the food) was the same in both cases. In this thesis we looking at the lack of precision and the variation of ship arrivals which affects delivered goods and services in the terminals or ports. Even if we are not to measure the kind of services described above precision of arrival and departure is a sign of ***quality*** for the customers. Some customers may not see the late arrival of a ship as a problem, but others may do. Quality it thus one of the most important parameters for the customers in every terminal and port to understand and handle.

2.2 Total Quality Management methods

"An operations manager's objective is to build a total quality management system that identifies and satisfies customer needs" (Heizer and Render, 2014)

For the terminals and ports to be able to look into these variations affect their operations they need historical data, methods and tools enabling them to be able to analyse the present situation and react in a timely and correct way. In combining the theories and tools of Lean and TQM the terminals, ports and ships should have a way of improving the ***quality*** of their service operations and doing this in a Just-in-time (JIT) manner.

2.2.1 Effects of quality

The effects of quality are having big impact on the ***company reputation***, ***product liability*** (injuries and damages) and ***global markets***. In the present age where of technology and data ownership and analysis plays increasingly bigger role, a good Total Quality Management using these right method and tools may give a better reputation. I would also lower the risk of injuries or damage to life, health or property, which in turn may affect the global cargo flow and thus increased cargo operations and revenues. Improving or decreasing quality also have a Cost of Quality (COQ). These are shortly summarized up below, but should also be considered in a cost-benefit aspect (Heizer and Render, 2014).

- Preventive cost (E.g. prevent machine defects; training, quality improvement programs)
- Appraisal costs (E.g. Quality control; testing, labs, inspectors)
- Internal failure cost (E.g. Defects during production; rework, scrap, down-time)
- External failure cost (E.g. Defects after delivery to customer; rework, returned goods, liabilities, lost good will, cost to society)

"Total Quality Management (TQM) refers to a quality emphasis that encompasses the entire organization, from supplier to customer." (Heizer and Render, 2014) the effects of quality are thus not to just increase a bit has the goal of increase quality and value through the whole supply and value chain.

By using TQM the goal is to improve the quality and hence increase the profits by building a system of quality assurance which meets the customers need in the whole organization.

2.2.2 Continuous improvement

One of the important elements in TQM (and Lean production manufacturing) process is the Principe of ***continuous improvement,*** where PDCA (Plan, do, check, act) method (also called a Shewhart circle) developed by Walter Shewhart, is used in some form. A competing cycle is the PDSA developed by Dr. W. Edwards Deming in Japan after WW2. *"The basis of the philosophy is that every aspect of an operation can be improved"* in a *"[…] never ending process of continuous improvement […]"* (Heizer and Render, 2014)

The difference between PDCA and PDSA is that the PDSA's third step emphasises *"on Study (S), not Check (C) ",* the dissimilarity lays in that *"[…] the Check phase of the PDCA cycle focuses on the success or failure of a Plan, followed by needed corrections to the Plan in the event of failure […]" while* the Study phase of the PDSA cycle focuses *"[…] on predicting the results of an improvement effort, studying the actual results, and comparing them to possibly revise the theory."*

The visualization of a PDSA (Deming circle) is seen below.

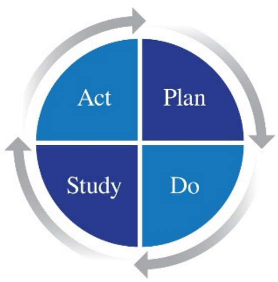


Figure 5 Plan-Do-Study-Act (Deming Circle) (Deming, 2018)

Both approaches are fully in alignment with TQM, but it is advised to know about the differences of method, where the PDCA checks the outcome a plan and the need for corrections to the plan, the PDSA adds the elements of study and the possibility to revise the theory is self. PDSA thus adds the level of changing the theories on which the plans and checks are build.

As discussed by Heizer and Render (Heizer and Render, 2014) there are two ways quality improves the profitability, either by ***"Sales Gains via, improved response, flexible pricing or improved reputation"*** or ***"Reduced Cost via, increased productivity, lower rework and scrap cost or lower warranty cost"*** (Heizer and Render, 2014)

According to Heizer and Render the way to achieve TQM, is to go through a flow of activities necessary to achieve TQM. Going from the *Organizational practices* to *Quality principles*, *Employee fulfilment* and *Customer satisfaction* as shown in Figure 6 below.

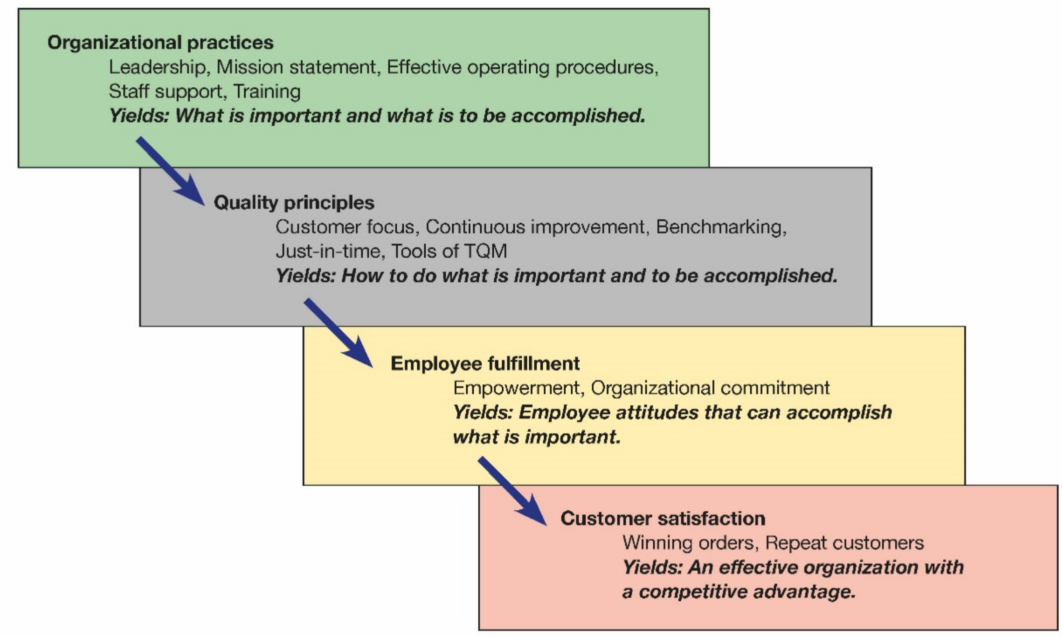


Figure 6 The Flow of Activities Necessary to Achieve Total Quality Management (Heizer and Render, 2014)

The figure shows *"flow of activities for an organization"* going from "Organizational practices ", "Quality principles", "Employee fulfilment" to "Customer satisfaction". This flow of activities should be used to *"achieve total quality management (TQM)"*. (Heizer and Render, 2014) Let's take a look at what these flows of activities are. In order to travel the path of this flow we need to know the method and have the tools necessary. Let's first describe the method of flow.

In the first "flow" level ***"Organizational practices"*** the activities to be followed, are those of *Leadership*, *Mission statement* (describe goals and objectives), *Effective operating procedures, Staff support and Training*. Here we take a look at what the goals and objectives are and how this can be achieved. The managements responsibility is to govern in a way that enables the company to reach these goals and objectives. The yield being to know *"What is important and what is to be accomplished."* (Heizer and Render, 2014)

In the second level ***"Quality principles"*** the activities should be on *Customer focus, Continuous improvement* (E.g. Plan-Do-Check-Act), *Benchmarking, Just-in-time (JIT)* and the usage of the *Tools of TQM*. Here we look at how things are done and how they can be improved using the appropriate TQM tool. The yield is to know *"How to do what is important and to be accomplished."* (Heizer and Render, 2014)

In the third level ***"Employment fulfilment"*** the activities should be that of *Empowerment* and *Organizational commitment*. Here the employees' *motivation* and *will to do things* the right way is addressed. The yield wanted is to have *"Employee attitudes that can accomplish what is important."* (Heizer and Render, 2014)

In the fourth and last "flow" level ***"Customer satisfaction"*** the goal is to *Winning orders, Repeat customers*. This is what we want to achieve, by using TQM methods and tools on the whole flow it might be easier to reach. The yields are to have *"An effective organization with a competitive advantage."* (Heizer and Render, 2014)

2.2.3 The TQM concepts

W. Edwards Deming used "14 points […] to indicate how he implemented TQM" (Heizer and Render, 2014). The concepts that Deming developed are thus the basis of much of the TQM concept written later on. The American Society for Quality (ASQ) have them listed as follows (American Society for Quality, 2018):

1. Create constancy of purpose for improving products and services.
2. Adopt the new philosophy.
3. Cease dependence on inspection to achieve quality.
4. End the practice of awarding business on price alone; instead, minimize total cost by working with a single supplier.
5. Improve constantly and forever every process for planning, production and service.
6. Institute training on the job.
7. Adopt and institute leadership.
8. Drive out fear.
9. Break down barriers between staff areas.
10. Eliminate slogans, exhortations and targets for the workforce.

11. Eliminate numerical quotas for the workforce and numerical goals for management.

12. Remove barriers that rob people of pride of workmanship, and eliminate the annual rating or merit system.

13. Institute a vigorous program of education and self-improvement for everyone.

14. Put everybody in the company to work accomplishing the transformation.

Heizer and Render suggest a similar path but reduces the 14 points made by Deming to the following six concepts *"[…] (1) continuous improvement, (2) Six sigma, (3) Employee empowerment, (4) benchmarking, (5) just-in-time (JIT), (6) Tagushi concepts and (7) knowledge of TQM tools." (Heizer and Render, 2014)*

A terminal or port should look into all of these concepts to see if and how these principles can be used. The goal is to improve the quality of their services. This cannot be done without the commitment to implement TQM system in the whole organization (from supplier to customer) coming from the management, involving all elements from design to maintenance. According to the article "Employee involvement and quality management" written by Hongyi Sun, Ip Kee Hui, Agnes Y. K. Tam and Jan Frick, Employee Involvement (EI) *"[…] is positively correlated with total quality management (TQM) enablers"* and *"EI is positively correlated with improvements in business performance"* and *"EI positively influences the contribution of TQM to the improvement of business performance" (Sun et al., 2000)*

In this master thesis we will mainly use the concepts of *continuous improvement*, *benchmarking* and *JIT,* in addition to *knowledge of the TQM tools.* The concepts of interest are shortly described below as a summary from Chapter 6 in Heizer and Render's book "Operations Management – Sustainability and Supply Chain Management" (Heizer and Render, 2014). Some of the tools described below are also described in more detail in the master thesis.

Concept /Tool	Cause	Effect	How
Continuous improvement	Lack of quality	Continuously improves the utilization of "people, equipment, suppliers, materials and procedures".	Use a never ending PDCA/PDSA circle

Benchmarking	Lack of "best practice" methods	Improve "products, services, costs or practices for processes or activities similar to your own".	Select and use benchmarking standards and continuously collect data to use.
Just-in-time (JIT), Scatter Diagram, Histogram, Flow chart, Statistical Process Control Charts, Cause-and-Effect Diagram	Muri	"Cuts the cost of quality", Improves quality", "Better quality means less inventory and a better, easier –to-employ JIT system"	Continuously solve problems. Change processes.

Table 2 TQM Concepts used in the master thesis

2.2.4 The TQM tools

As seen in the table and figures below there are many tools that can be used. One of the main principles of TQM is to *"[…] empower employees and implement TQM as a continuing effort, everyone in the organization must be trained in the techniques of TQM,"* (Heizer and Render, 2014)

The organization themselves need tools to achieve TQM, and they need to be trained in how to use them. The tools may be used stand alone or are in combination this depends on type of company, type of organization and where these tools are to be implemented in the organizations structure (E.g. in the management-, support- or operational level), company goals and type of operations. Different organizational levels may need different tools. And as stated earlier these tools need to be used in a never-ending process, only achievable if the management supports the process. Below is a list of the TQM "Tools for generating ideas", as well as some diagrams which show how some of the charts may look like.

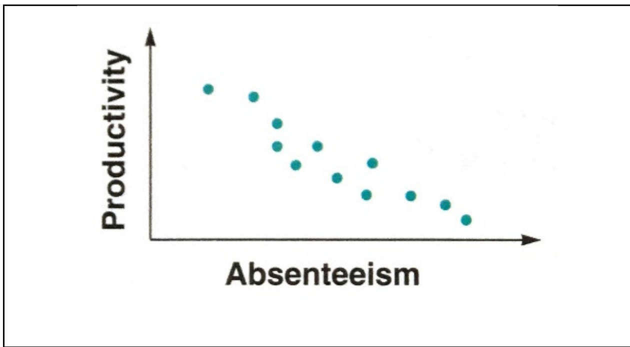
a) Check sheet b) Scatter Diagram c) Cause-and-effect Diagram	d) Pareto chart e) Flow Chart f) Histogram	g) Statistical Process Control Chart

Figure 7 Tools for generating ideas

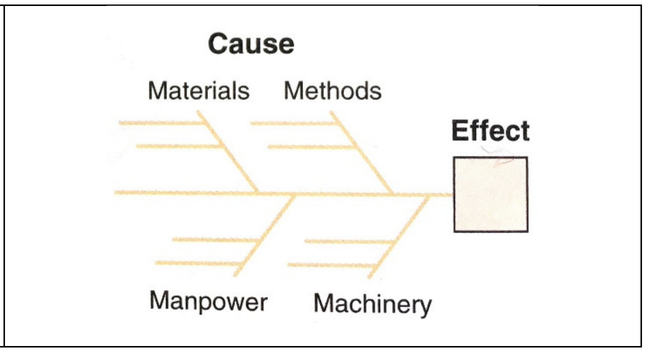
In this master thesis we will encounter tools of ideas that generate the b) Scatter diagram/plots, c) Cause-and-effect diagram, e) Flow chart f) Histogram and g) Statistical

Process Control Chart. There will not be any sheets of type (a) Check sheets or (d) Pareto chart due to the fact that they are not need in order to prove the theses correct or wrong, but they may prove valuable for registering and control of defects with other operational problems and in other situations.

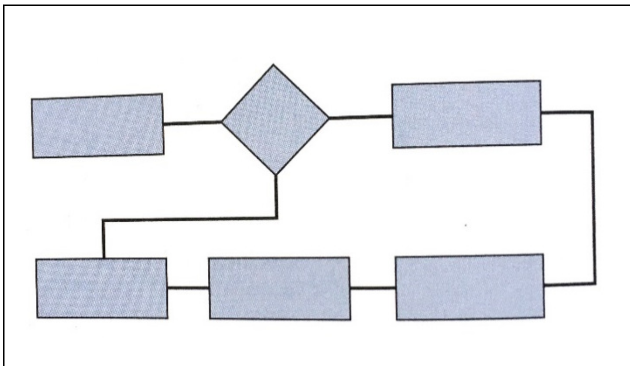
Scatter plot:



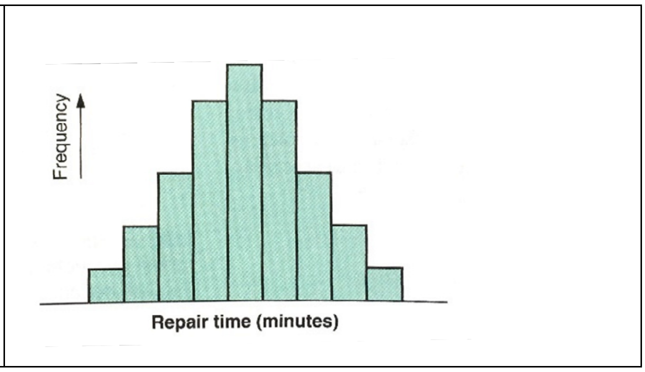
Cause-and-effect diagram:



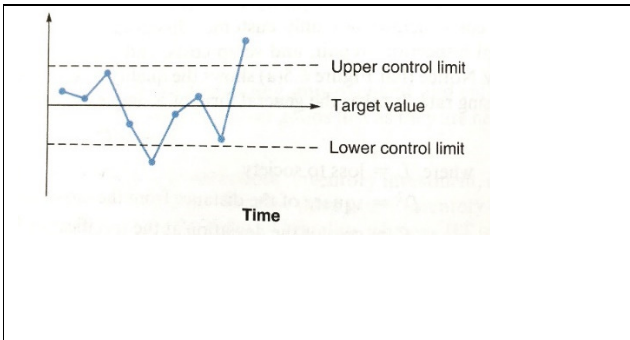
Flow chart:



Histogram:



Statistical Process Control Chart (I)



Statistical Process Control Chart (I):

R- and $\bar{X}$-Chart

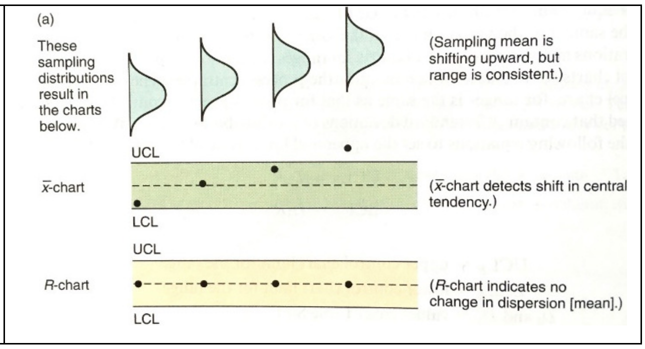


Figure 8 Different charts used in TQM (Heizer and Render, 2014)

Charts based on these will be explained later when they are used in the analysis chapter 4.5.1. There are also other tools that can be used in TQM like the *"Event-Tree-Analysis"* (Thai, 2015), where we look at barriers and the outcome of the barriers failing. The use of a bow-tie diagram can also be used for the same purpose.

2.3 Lean concepts and tools

As we saw in chapter 2.2 Total Quality Management methods above the TQM tools were first developed by Dr. W. Edwards Deming who was in Japan after WW2. In later years refined by others. In the TQM and Lean use the concepts Just-in-time and continuous improvements where *"The end goal is perfection, which is never achieved but always sought"* (Heizer and Render, 2014)

Wikipedia describes Lean as *"the systematic method for waste minimization"*. The figure below shows how the "Lean manufacturing house" is built up on robustness and using different lean tools ends up in the "Quality"-roof (Wikipedia, 2018b) where the goal is the minimum creation of minimal waste (Muda) through the never-ending circle of improvement (Kaizen) ant the other Lean tools. Waste is to be removed under "the perspective of the client who consumes a product or service". This increases the value for the customer and the willingness to pay. "[…] 'value" is any action or process that a customer would be willing to pay for." (Wikipedia, 2018b)

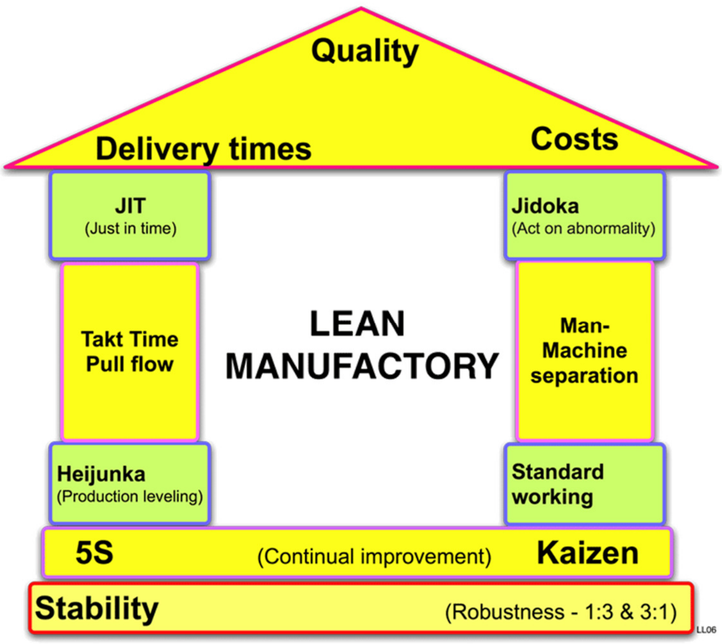


Figure 9 Lean Manufactory House (Wikipedia, 2018b)

For these tools to work we need a stable ground and the tools chosen will have big impact on time, resources and costs for the organizations implementing these.

As seen in Figure 9 above, Lean and TPS bases itself on two layers: (1) *Stability* (Robustness) and (2) *Continual improvement* of processes. *"Robustness is defined as reducing the variation of the functional requirements of the system and have them on target as defined by the customer […]".* (El-haik and Al-Aomar, 2006) The first layer of "Robustness" is important for the "house" to stand firm. Variations and their effects is an important aspect in the following analysis of the collected ship arrival and departure data. Without attention to robustness, changes done in the rest of the "house", will able to last over time. At worst, the rest of the house may "fall" or be "erased" to the ground, which can cause major losses or damage to owners, employees, customers and other stakeholders (E.g. NGO's or the rest of the society). Robustness is the key to sustainable solutions which are developed in "the rest of the house".

Processes and quality of products cannot improve without continuous improvement. The next level shown in the Lean Manufactory House below is the Kaizen (Continuous improvement) and 5S (workplace organization). These two tools/methods create the next ground layers for both pillars in and are central tools in the "Toyota Production System (TPS)".

The 5S tool is important, but is not described in great detail her as the master thesis has not looked into the workspaces in the ports or terminals themselves, but rather on the deviations to the ships visiting them. The 5S's circle has the objective of continuously organizing the workplace in an optimal way using the 5S's (Sort, Set, Shine, Standardize, Sustain). Kaizen on the other hand is needs a bit more explanation as this is very applicable on the variations to the ships arriving.

Kaizen is the Lean analogue to the PDCA circle in TQM. Figure 10 below shows the steps in Kaizen's continuous improvement circle used in Lean.

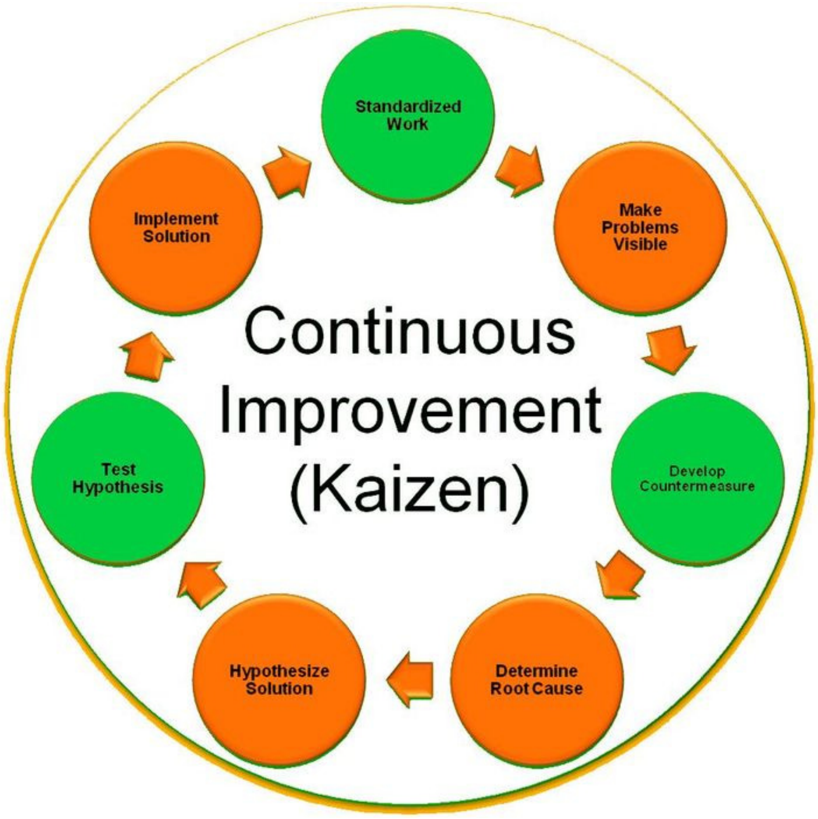


Figure 10 Continuous Improvement (Kaizen) (Formaspace, 2017)

As seen above the Kaizen tool goes in the same clockwise direction as the PDCA or PDSA. The major difference is that it has 7 steps describing the continuous improvement process. It starts with (1) Make Problems Visible, and has the following other "steps", (2) Develop Countermeasure, (3) Determine Root Cause, (4) Hypothesise Solution, (5) Test Hypothesis, (6) Implement Solution and (7) Standardised Work before the process start over again in a never-ending process. Step one (Make Problems Visible) can be visualized by Scatter Charts or the TQM tools shown in chapter 2.2 above, step two (Develop countermeasures), three (Determine root cause) and four (Hypothesize Solution) involves tools of "brainstorming", "Ishikawa" (cause-effect-analysis) and "5-Why" tools and techniques needed to reach the "hypothesize state". The rest of the steps are to test the hypothesis, implement solutions and standardise.

2.3.1 Lean Manufactory

The National Tooling and Machining Association define that *"Lean manufacturing is a generic process management philosophy derived mostly from the Toyota Production System (TPS) (hence the term Toyotism is also prevalent) and identified as "Lean" only in the 1990s.*

It is renowned for its focus on reduction of the original Toyota seven wastes in order to improve overall customer value." (NTMA Precision, 2009)

The original core of lean is thus to ***remove*** or ***reduce*** waste. According to NMTA there are seven core wastes in lean manufacturing to eliminate:

1. Overproduction
2. Waiting
3. Transportation
4. Inappropriate Processing
5. Unnecessary Inventory
6. Unnecessary / Excess Motion
7. Defects

Figure 11 The seven core wastes (NTMA Precision, 2009)

When reading or learning about Lean and the Toyota Production System (TPS) the one often encounter a reference to the three "M's". The three M's represents the first letter of each of the words naming the unwanted practices of ***"Muda"*** (Waste), ***"Mura"*** (Unevenness) and ***"Muri"*** (Overburdening). The lexicon at Lean Enterprise Institute also calls them the three M's that ***"[…] collectively describe wasteful practices to be eliminated"***. (Lean Enterprise Institute, 2018)

How can these three unwanted M's be imagined? Figure 12 below shows how Muri, Mura and Muda acts on the transport services of trucks delivering crates of goods. This example is a good analogue to ships and the cargo they move. The trucks below can in this respect be the imaginary "trucks of the seas", called ships.

The first examples show the three different ways that the three M's act, the last example is the example where we do not have any negative effects of overburden, unevenness or waste.

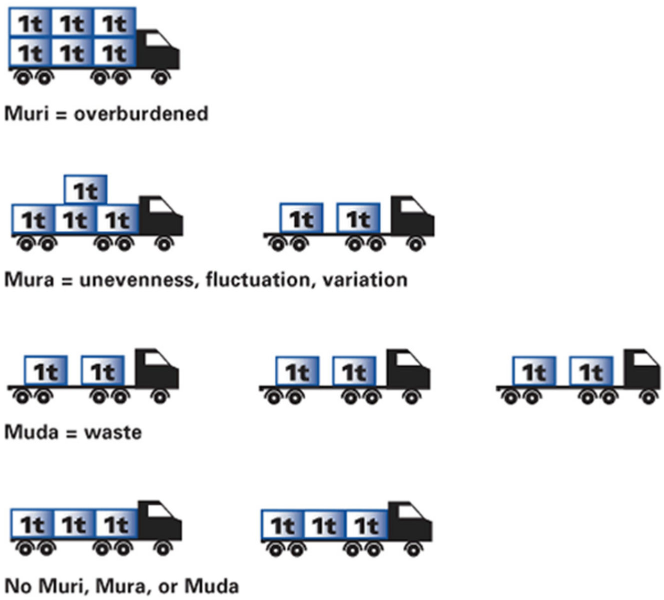


Figure 12 Effects of Muda, Mura and Muri (Lean Enterprise Institute, 2018)

The first example shows the situation of ***Muri***, where the truck (system) is ***overburdened***. In such a case there is more stress on the equipment which may break down (Defects).

In the second case ***Mura*** is described, where the trucks are bringing the goods to their destinations in an ***uneven way***, sometimes delivering too much crates of goods (overproduction) and at other times delivering fewer crates of goods than could have been transported and the customer may have to wait to receive the full order (waiting time). If the second situation is a situation where fewer crates are delivered than ordered by a consumer, this can in be a cause of the so called "bull whip" effect in a supply chain. The bull whip effect is described as being a *"Tendency of consumers of a material or product in short supply to buy more than they need in the immediate future."* (Business Dictionary, 2018a) and is not wished for as it creates stockpiles and the need for unnecessary inventory.

The third example shows how Muda can occur if the trucks are not fully loaded (Transportation). The overcapacity of one truck is the most likely cause here.

The last example shows how it looks when one of the trucks in example three is removed and the goods is divided equally between the two trucks. We then observe that there are no wasteful practices in the supply and value chain.

As presented earlier are two hypothesises presented in this master thesis,

H1:" New methods can make cargo transportation in North Jæren more profitable"

H2:" Changes can contribute to new cargo transportation in North Jæren"

And the wasteful practice is Mura (uneven workload), also called variance as shown in Figure 12 above, is the predominant and unwanted practice which the hypotheses are to look into, either to confirm and measure the impact of variance (Mura) or to suggest new methods for the increase of profitability for the ports in North Jæren. The other two "M's", Muda (waste), and Muri (overburden) is certainly present in the maritime supply and value, influencing quality and profit of the ports and terminals and should not be forgotten as they are an equally important part of Lean.

2.3.2 The Lean tools

"[…] understanding both what they are and how they can help is an excellent way to get started." (Vorne, 2017)

There are many lean tools to choose from, some of the most popular tools are listed up in Table 3 below. It takes 4-5 years to implement Lean in a small to medium sized enterprise (SME), and may take longer time in bigger companies, therefore *"[…] One of the most important things to take into consideration […] is the application of an adequate problem solving technique[s] to avoid waste."* (Iuga and Rosca, 2017) We should listen to experts and plan before we choose (PDCA).

Top 25 Lean Tools		
5S	Kaizen (Continuous Improvement)	Single-Minute Exchange of Dies (SMED)
Andon	Kanban (Pull System)	Six Big Losses
Bottleneck Analysis	KPIs (Key Performance Indicators)	SMART Goals
Continuous Flow	Muda (Waste)	Standardized Work
Gemba (The Real Place)	Overall Equipment Effectiveness (OEE)	Takt Time
Heijunka (Level Scheduling)	PDCA (Plan, Do, Check, Act)	Total Productive Maintenance (TPM)

Hoshin Kanri (Policy Deployment)	Poka-Yoke (Error Proofing)	Value Stream Mapping
Jidoka (Autonomation)	Root Cause Analysis	Visual Factory
Just-In-Time (JIT)		

Table 3 Top 25 Lean Tools (Vorne, 2017)

The list above is meant to show that there are a lot of tools to choose from, and we should use some time before we choose which tools applies to each case. In this master thesis we will look at how ship arrivals are effected by variance, Lean tools like *Just-In-Time (JIT), Kaizen (Continuous Improvement), KPIs (Key Performance Indicators), PDCA (Plan, Do, Check, Act), Root Cause Analysis* and *Muda (Waste)* can make a difference if used correct.

2.4 Theory and Literature

The theory literature used has been collected from the internet and books describing the TQM and Lean methods and tools which are the two predominant research fields concerning "unevenness, fluctuation and variation" (Mura) and quality of services and goods.

Both Total Quality Management (TQM) and Lean are well known theories with world-wide used methods and tools and have good research results to show off in other industries. Most of the theory around TQM has found in the book "Operations Management, 11th edition" (Heizer and Render, 2014) by Jay Heinz and Barry Render.

There are some other literature concerning the quality in maritime transport, but it is not that well known in the maritime industry as of yet. There is some work done by Dr Thai Van Vinh, who has made models on *"Quality in the Maritime Transport"* called the **ROPMIS** (Resource-, Outcomes-, Process-, Management-, Image/reputation- and Social responsibility related maritime quality), **PSQ** (Port Service Quality) and **LSQ** (Logistics Service Quality) (Thai, 2015) These models are only referred to and not used as such in the master thesis, but it gives a good introduction to the aspects of quality in the maritime sector.

When coming to Lean there is an abundance of literature and resources available on the internet. It is almost impossible not "to get lost". This has therefore been easy to find, but it is not always that well explained. It has therefore been of importance to collect the theory literature from the perceived best internet sites.

All in all, the general literature found on TQM and Lean has been mostly presented from the goods producing world, but the theories are also applicable if used with the knowledge that services are intangible in their nature. The full list of literature can be seen in the “Reference list”.

3 Method

This master thesis uses a mix of ***quantitative***, ***qualitative*** and ***case*** methods and ***inductive reasoning***. During the data collection and analyse and during the verification and discussion phase there have been a need for ***unstructured interviews***. A quantitative method uses data are objective in their nature. In a qualitative method data are subjective as humans as we are restricted by our cognitive limits, feelings which are affected by the outside. This influences the way of reasoning and interpretation (Hermeneutics). The master thesis reference list and in text references follow the Harvard reference standard.

3.1 The case and inductive method

The master thesis also uses the ***"Case"*** form when it looks into ship arrivals and departures, coming to and from Sandnes Havneterminal AS owned by The *Port of Sandnes*.
A case is a defined as *"[…] a particular situation or example of something" (Cambridge Dictionary, 2018b)*. It frames which situation and example the master thesis looks into. A case is also a way to keep the work within the frames and extent of what can be expected from a master thesis. The Sandnes Havneterminal is mainly handling conventional cargo operations ships. It has mostly traffic of the ship types "General Cargo Ship", "Ro-ro Cargo Ship", "Refrigerated Cargo Ship", "Palletised Cargo Ship" and "Container ship". The study does thus not take in to account "Other vessels", like "Dry bulk" and "Wet bulk" in the study.
The case assumes that the initial findings in the *Port of Sandnes* (Sandnes Havneterminal AS) can be used to pave the way for the conclusions drawn for North Jæren area and beyond (Rogaland). It is therefore important to be aware of the inductive reasoning that implicit occurs when going from "a some to all reasoning".
In using inductive logic, it needs to make clear that this kind of reasoning does not give us an exact answer. Doing more observation brings us closer to a correct answer. A hypothesis based on an inductive method of reasoning is not expected to have an explicit answer, but doing more observations has as goal to get as close to it as possible. In order to accept or refute the results of the hypotheses, "two questions need to be answered" (deLaplante, 2013)

1. How strong is the inference? (What is the ***probability*** of the conclusion, given the premises?)

2. How high does the probability have to be before it's rational to accept the conclusion? (What are the ***thresholds*** for rational acceptance? Is the argument strong or weak?)

To define the threshold is *"an unresolved problem to philosophy of inductive reasoning"* because *"it gets into what is known as the problem of induction […] on how you justify inductive reasoning in the place"*. The problem of induction was first formulated by *"the Scottish philosopher David Humes"* where the formulated problem is where to set the thresholds of weak or strong interferences. There is no exact solution to this problem, *"the best we can say is that <u>it is a conventional choice</u> where <u>we</u> set the threshold"*. (deLaplante, 2013)

3.2 The interviews

The interviews are performed in the form of "Unstructured interviews" (Informal interviews) which *"[…] are sometimes referred to as 'discovery interviews' & are more like a 'guided conservation' than a strict structured interview."* (McLeod, 2014)

As discussed by Saul McLeod the strengths of *unstructured interviews* over performing *structured interviews* are: "[A:] *Unstructured interviews are more flexible as questions can be adapted and changed depending on the respondents' answers. The interview can deviate from the interview schedule.* […] [B:] *Unstructured interviews generate qualitative data through the use of open questions. This allows the respondent to talk in some depth, choosing their own words. This helps the researcher develop a real sense of a person's understanding of a situation.* [… C:] *They also have increased validity because it gives the interviewer the opportunity to probe for a deeper understanding, ask for clarification & allow the interviewee to steer the direction of the interview etc."*
The down-side and limitations of such an interview method is that *"1) It can be time consuming to conduct an unstructured interview and analyze the qualitative data (using methods such as thematic analysis). 2) Employing and training interviewers is expensive, and not as cheap as collecting data via questionnaires. For example, certain skills may be needed by the interviewer. These include the ability to establish rapport & knowing when to probe."* (McLeod, 2014)
By knowing that the interviewer and the design of interview (E.g. which gender/ age, personal characteristics and ethnicity) can have an effect it can have a big effect on interviews, the

author (Terje Rygh) recognize his limitations, and is not an interview expert which has undertaken classes or courses in interview techniques. The intent has throughout the course of the master thesis and the interviews to be impartial and objective, asking non leading open questions to the respondent and be unbiased in each interview in order to make as objective interviews and interpretations as possible.
The author sought to get an insight from different angels and have objectivity and keep an integrity in both interviews, data collection, analysis and conclusions.

3.3 Research design, model and methodology

In all research some phenomenon is observed, where observation data is collected in some form or another. The data is later used to analyse and draw conclusions from in order to test a hypothesis. The hypotheses in turn is then either found false or correct. The research is seldom linear and the hypothesis development may need time to mature due to the changes of "characteristics to measure" and new data or vice versa.
In order to document what is done and in order to have a good structure on what to observe and what observation to collect, research design and data collection models and tools are needed. The final hypotheses and what to measure and collect is thus often a result of several directional changes to in these iterations.
In both of the postulated hypotheses, the logic reasoning goes from few observations over to assuming that this applies for all future observations. Much of the data is collected for the first hypothesis ***(H1)*** are based on observations and not theory. This means that the reasonable way to verifying this thesis is by using ***inductive logic***[3] (also called inductive inference).
The work done in the second hypothesis (H2) is based on more a more subjective analysis because of lack of empirical data. The collection of alternatives was through "brainstorm" put up in excel matrix and weighted based on subjective values/grades, as well as a by making a "Ishikawa" (cause-effect-analysis) in a fish-bone diagram. This is very similar to the PDCA/PDSA and Kaizen, used in TQM and Lean. The alternatives found for the second hypothesis (H2) were a collected of own experience, conversations and research in the internet and from news and newspapers.

[3] Described in chapter 3 Method

In the following chapters the research design and method is explained in order to get insights in how the processes leading forward to the final hypotheses and observation data to collect was.

3.3.1 The research model

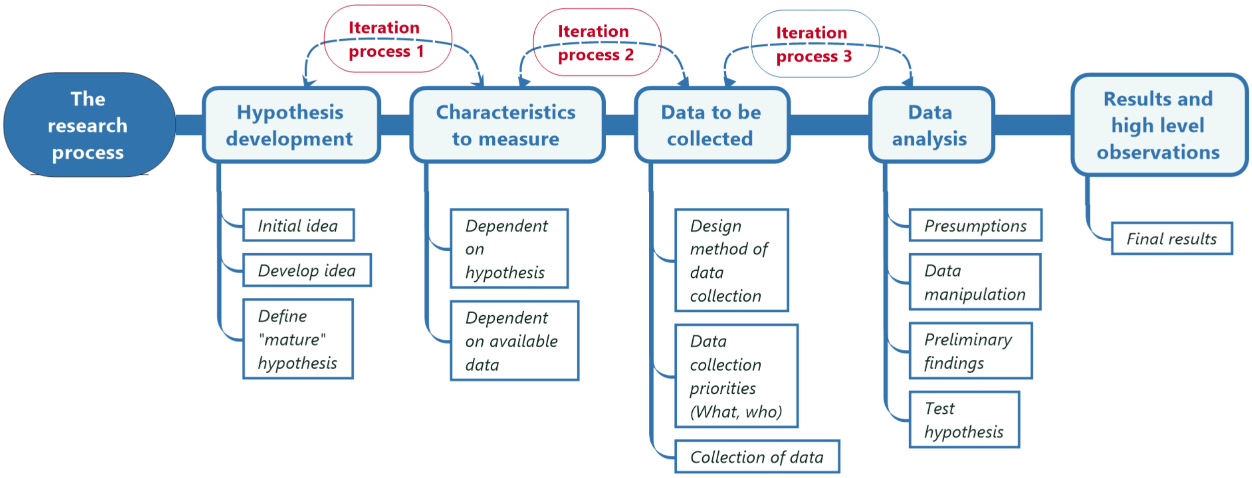


Figure 13 The research and data collection process

The data research and data collection process can be seen as several iterations as seen in Figure 13 above adapted from the master thesis *"An evaluation of the New Product Development process in the context of Operational readiness"* (Jordaan, 2016) of Lyndall Jordaan . This enables a better overview and documentation of why and how the data has been collected. The end product is a data collection plan as described in

Figure *14* below.

The research process starts with "Iteration process 1" going through "Iteration process 2" and "Iteration process 3". Each of these iterations connects two steps needed in order to develop hypotheses. The first iteration takes place between the "Hypothesis development" and "Characteristics to measure". At first the hypothesis is an idea, then the hypothesis idea develops from iterations with the "Characteristics to measure". Later when all the iterations down in the "chain" have reached a certain maturity level the hypotheses may be defined, at some stage the hypothesis is not changed any more, as the final "mature" hypothesis. In the second iteration process the interaction goes between the "Characteristics to measure" and which "Data to be collected" (Observation data). This iteration step influences the whole "Collection of data" process in all from which data to collect (Hypothesis/Characteristics to measure), which method of data collection (collect historical data, conduct interviews) and prioritizing (what) and where (who) to find these data. All of this in turn leads to the third iteration process where the previous two iteration steps may be changed due to new presumptions and preliminary findings. In the end the data manipulation follows with the analysis and the hypothesis testing. With data manipulation is meant the step where invalid data or the data population is changed (filter or data selection) or new calculations are added like the difference in time between an estimate time (ETA, ETD) and actual time of arrivals (ATA, ATD) or departures. When this is done in a good manner, it may give a better result and these steps can be understood and judged by others.

In the work on this master thesis, iterations were used several times in both “up and down” directions in order to ensure a good “base layer” before the test of the hypotheses. During the iteration process and maturing process, interviews were made with maritime experts. This also helped to develop and formulating a sound hypothesis, with the right characteristics to measure. The interviews in turn ensured that the right data sources and was collected and analysed. The interviews were thus important for identifying areas to look into. These interviews and follow-up interviews were used in confirming the findings of this master thesis. In the end the goal was to gain the best objective and solid ground for gaining high level observations and final results.

3.3.2 The process from hypothesis to higher level observations

The main steps in Figure 13 above, are repeated in

Figure *14* below which contains a numbering and colour schema used for later references, explanation and linking. The process leading up to the final analysis and result was made through several iterations as explained in the last section. An important observation is that the process itself and the resulting diagram seen in Figure 3 below is showing the results on how things act together and where the loops of continuous processes are. The legend explaining the figure is found in Table 4 below. The result of the multiple iterations can be seen here in a figure adapted from the master thesis (Jordaan, 2016) of Lyndall Jordaan:

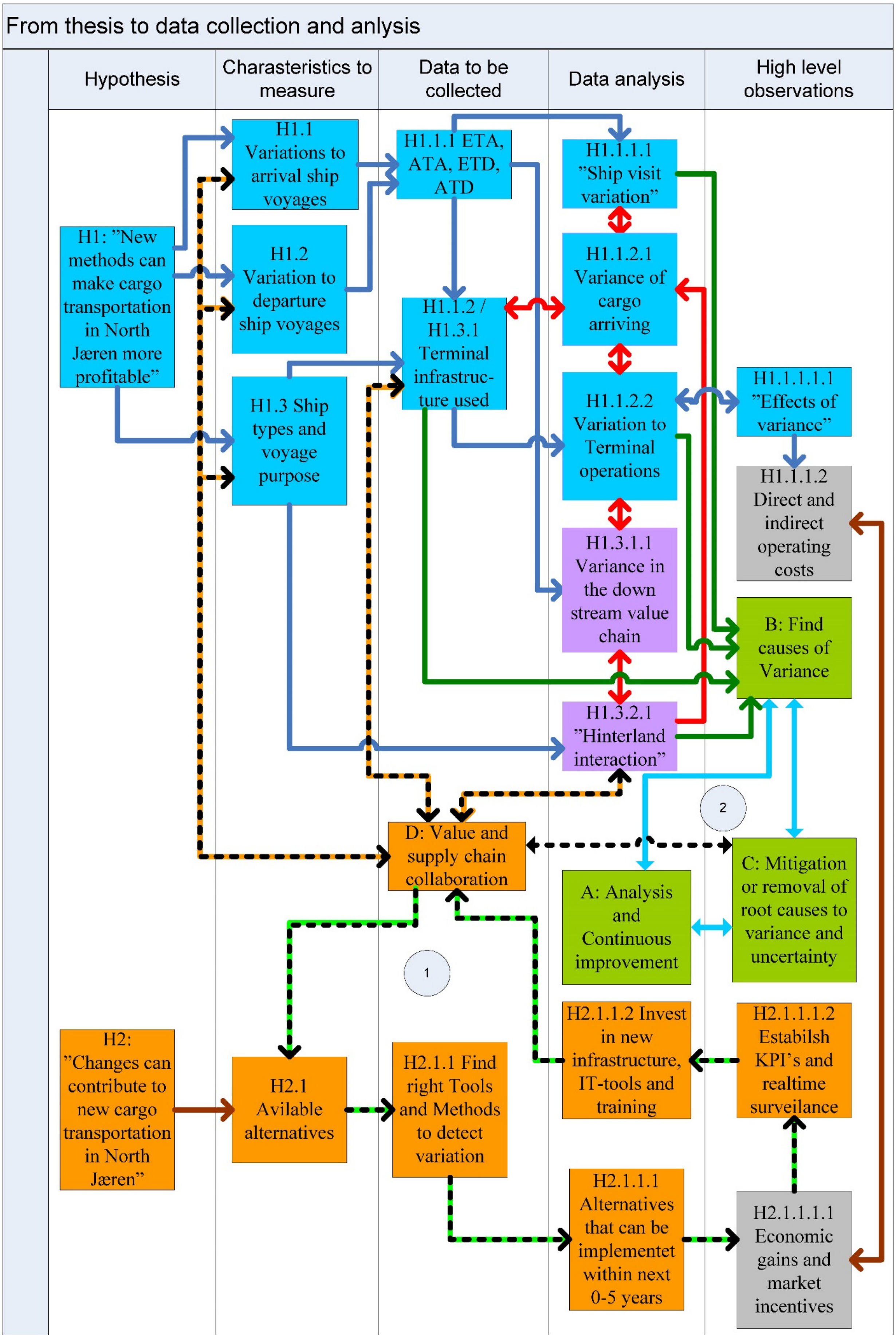


Figure 14 "Going from hypothesis to high level observations"

The column texts in

Figure *14* describes the research process from generating the hypothesis all the way to the higher level observations. It also shows how the characteristics, the data to be collected, and the data themselves are connected from the hypothesis to the high level observations. As we see each box has a connection line and each box connected has a reference number or reference letter. These identifications are used later to back-reference and describe just where we are in these "steps" in the analysis and the discussion chapter. There are also several colours on the "boxes" and the arrows going between them and two circles with the numbers 1 and 2 in them. These colours and symbols have different meaning. The following legend explains what these colours and symbols represents.

Symbol / colour	Description
(Blue background)	The hypothesis H1's "path" to high level observations
(Lavender background)	Hinterland / Downstream value and supply chain
(Orange background)	The hypothesis H2's "path" to high level observations
(Grey background)	Economic results and incentives for change
(Green background)	Variation detection, mitigation and continuous analysis and improvement
(Dark blue line w/Arrow)	Ship voyage variation and "downstream" effects
(Red Arrow w/Arrow)	Hinterland supply chain and "upstream" effects
(Brown line w/Arrow)	Hypothesis H2's characteristics to measure / cost from effects of variation
(Light blue line w/Arrow)	Direction of continuous improvement loop
(Black dotted line w/Arrow)	Link between Stakeholders and the continuous improvement loop (Operational link / control)
(Black and orange dotted line w/Arrow)	Value chain real-time collaboration and data sharing
(Black and green dotted line w/Arrow)	Infrastructure, support functions and human resources
1 (Loop number 1)	Collaborative loop: stakeholders supply and Value chain + internal resources Reduce variance, waste (Muri, Mura, Muda), increase quality
2 (Loop number 2)	Continuous improvement loop Plan-Do-Check-Act / Kaizen
The direction of the arrow(s) shows where the information or information logic moves.	
H1.1.1 and H2.1.1, A, B, C, D are examples of the elements label/numbers for possibility of back-tracking to these elements inn later text.	

Table 4 The Figure and Colour Legend of

Figure 14 "Going from hypothesis to high level observations)

The benefits with the numbering and colour schema in

Figure *14* is that we can easily use the numbering logic to for back reference and keep track of where we are. The arrows, lines and symbols makes it easier to explain relationships and logic between sections. They also show the “path” of the individual hypothesis and the relationship between the hypotheses, as well as the two continuous improvement loops in which TQM and lean tools are used to improve the quality of services and the value to the customers is increased.

4 The road leading up to the experiments

This chapter goes more in-depth through the main steps described above.

The opening challenge is to know exactly what to look for and to limit the scope within what is a reasonable frame for writing a master thesis. Going from the Figure 13 in chapter 3.3.1 above to the result in

Figure *14* is not made "at a glance". It is a process that need both insight and time to mature.

Each step, interconnection and logic in

Figure 14 "Going from hypothesis to high level *observations*" has been tried described. As said earlier by referring to the codes, colours and symbols (Arrows/Circles) we can easier back-track and better follow the stepwise approach from the first building a hypothesis thesis to the higher level observations in later text. If there are any critical features in the data analysis or in the way up to the analysis that needs commenting or criticism this is also included when found.

The first step in the Kaizen circle says that "Make problems visible". In the steps leading to the visualization lean tools like "Brain storm" and "5Why" in combination with QTM tools like "Cause-effect"- and "flow"- diagrams may visualize the problems, but also make us aware of the situation with the problems. Let's take a look at two diagrams used in this master thesis.

4.1 The characteristics to measure (H1.1, H1.2, H1.3, H2.1)

Before starting start to collect data we need to know which characteristics we want to measure. During   After we start developed the hypothesis in most cases we will have some idea on which data to collect in order to, as we mentioned in chapter 4, to verify if the hypotheses are correct or wrong.

But how to collect data by knowing this, we also know which data we would like to collect.

This process is very important and have to be refined several times as the research process has matured. The goal has been to find elements that can support the theses and can lead to high level observations.

4.1.1 "Ishikawa" / Fishbone diagram: Cause – Effect analysis

The way leading up to the data collection there is a need to know what problems to look at. In building a cause-effect diagram as seen Figure 15 below, we can observe effects and their causes in a detailed way and see where one cause affects the outcome.

The different effects were categorized in the following main areas: "Environment" (Effects and causes to waste of on nature and resources), "Material" (Effects to waste of physical objects and their limitations), "Human" (Effects and causes to human limitations of creating output), "Machine" (Effects of waste in using machines wrong), "Systems" (Effects of lack of or inadequate supportive systems), Methos (The effects of lack of methods and its waste) and "Infrastructure" (Lack of infrastructure and its effect on operations).

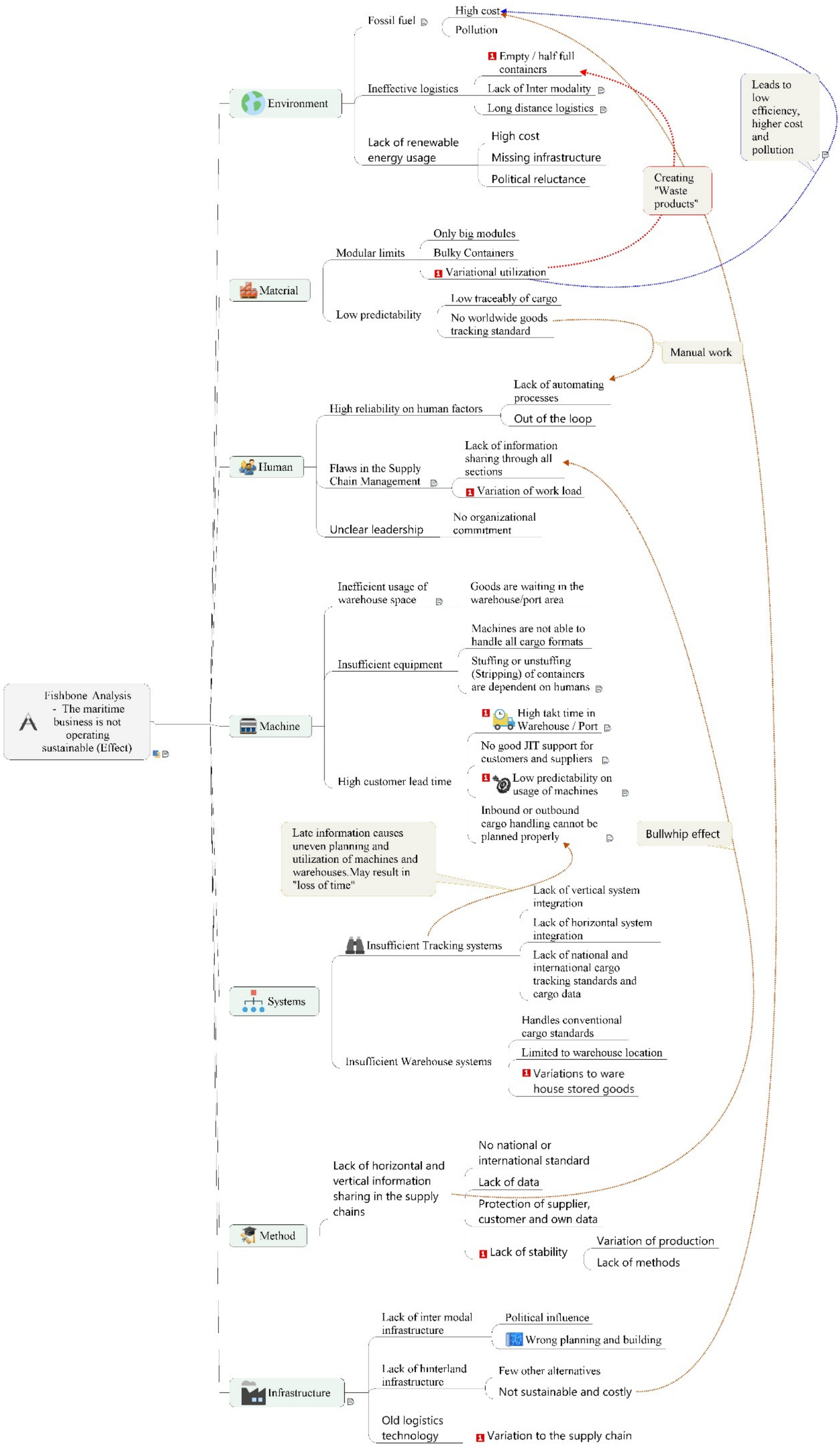


Figure 15 Brainstorm; Cause - effect diagram (Ishikawa / fish bone diagram)

In looking at all of these main aspects, the effects and causes for unwanted “waste” the thing that seems to influence all of the categories mentioned above is the effect of variations. This is one of the reasons why we need to look at the variations in the supply chain, and use tools methods leading up to KPI’s that can be used for operations surveillance and benchmarking as shown in chapters 2.2.4 and 2.3.2, where we use the KPI’s of Mean/average (CL), Standard deviation, Upper Control limits (UCL) and Lower Control Limits (LCL).

4.1.2 Flow Chart: A simplified Supply chain – India to Norway

Below we see the simplified Supply chain describing a "imaginary" voyage (may also be real), which shows the many supply chain steps inside a "Contract of carriage" between the two main parties "The goods seller/owner" and the "The goods buyer/Consignee", of goods coming from somewhere in India, to somewhere in Norway. We see on the left side of the supply chain that it starts with a the "Contract of carriage" when a sale or rental/leasing agreement is in place, which in turn affects other contracts with other parties and pick of transportation methods and transport ways. The important thing for the Consignee it that the goods has the right quality and comes

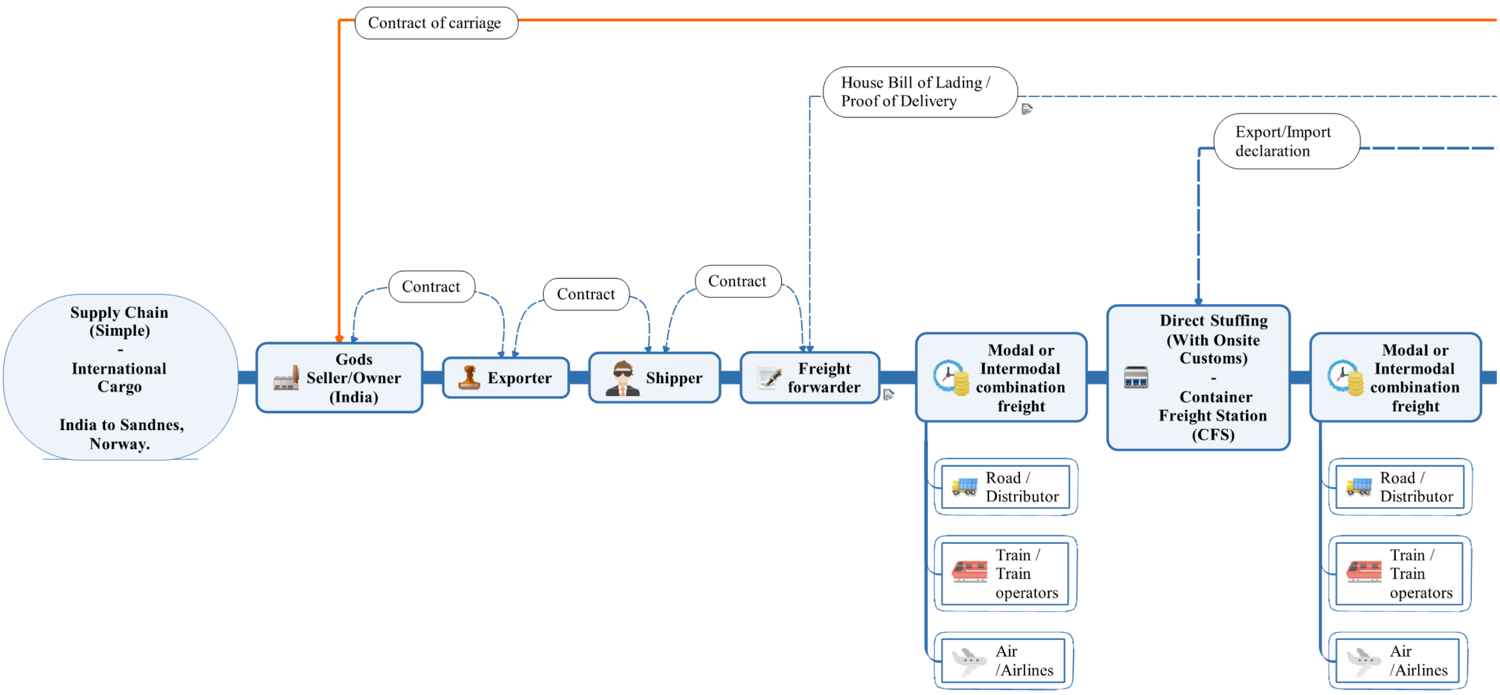


Figure 16 Simplified supply chain - India to Norway – Part I

undamaged, and JIT at the end-station. In all of the steps seen in the supply chain may cause variation and affect the quality of services or end product. In this example there are many "stations" and intermodal choices which affects the flow and the variance. One "mishap" in one place or a bottleneck may cause the ripples in the downstream direction to be big. The

TQM and Lean methods and tools should contribute to mitigate the effect of variance to the quality of the delivery and product. In the further work of the master thesis we are going to look at the interactions between the ships and how their arrival time affects the operations in the first downstream joint, which is the interaction between the ship and the terminal or port that it has the intention of visiting. A late arriving ship may not only unload its cargo late, but also have to load the next cargo on board the ship later due to the delays. By drawing a simplified flow chart like the one below we are using one of the TQM tools described briefly earlier. By looking at the flow chart we see that the port is an essential part of this example. We also see that there are many

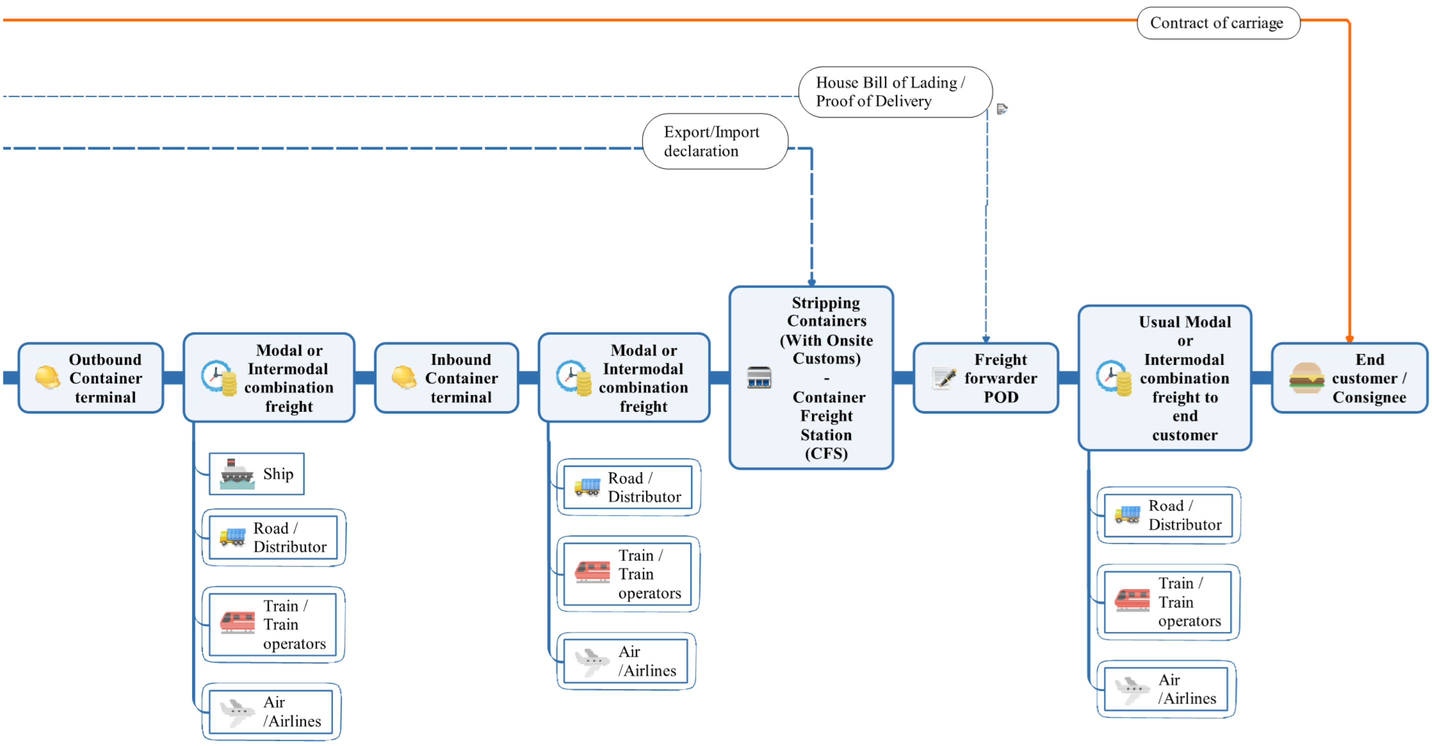


Figure 17 Simplified supply chain - India to Norway – Part II

other modal transport opportunities. For the ship industry to be competitive it needs to be both cheap and efficient so that the customer chose the sea freighter over other transportation methods (air, road, rail). The ports and terminals may be bottlenecks, but they need the stability of the "Lean house" to build something sturdy and lasting to be able to do the best possible job for the customers. The master thesis has as said only looked at the variance coming from the ships and that affect the “first joint” of the whole value- and supply chain shown above. It is also not looking at waiting times or “local” sequences of operations following a ship arrival in the terminals themselves, neither does the master thesis look into how this affect the supply chain. Such a study could have put a “restricted access” on the master thesis paper, which the author has tried to avoid. Another factor of why the downstream and “waiting time” study has not been performed is that this kind of research is time consuming, it would need more resources than is available for this master thesis. By having looked at the cause-effect diagram in the previous chapter and the flow chart above we can conclude, that the variations of ship arrivals play a big role for the terminal and port operations.

4.2 “Variations to arrival ship voyages” (H1.1) & “Variations to departure ship voyages” (H1.2)

In these two characteristic to measure, it is meant that the master thesis should look into how the ships arrival and departure variance affect their punctuality. With punctuality, is meant if they came early or later or Just-in-time as planned/estimated and intended schedule. Thera are three aspects of ship variances that will be looked into.

(I) The variable variance (1) is a dependent variable (y-value in a scatter plot), presumed to be dependent on the “Notification time” (2) and number of updates (3) called independent variables (x-value in a scatter plot). This means that we have one independent and two independent variables and that variance is not only affected by the time of update (“Notification time”) but also on how many times we update. Assuming that a ship knows closer to the arrival, it may have a better prediction reporting later on in a voyage than early, even if they only report once. The same goes for when a ship updates several times, assuming that updates are done because we have new information, the latest update should have a better prediction than the earlier. The precision and punctuality is thus dependent on time of notification and how often a ship updates.

(II) Calculating how much the variance totals to in number of hours and cost. This will later be used as a baseline that new methods and “available alternatives” (H2.1) can improve operations and from which terminals and ports can profit from.

(III) Are ships later arrival time than scheduled also leaving later than scheduled. The results can indicate if there are some bottlenecks (muri) or overcapacity (muda), if there are no strong correlation this could be a sign of uneven workloads (mura).

These are discussed more in the "Data analysis" step for hypothesis H1 (H1.1.1.1, H1.1.2.1, H1.1.2.2, H1.1.1.2, H1.3.2.1) and hypothesis H2 (H2.1.1.2, H2.1.1.1).

4.3 "Ship types and voyage purpose" (H1.3)

These characteristics are meant to look into if ship types or voyage purpose have an effect on the variance. Here the variance is still the dependant variable, and the ship type and voyage purpose are the independent values. Looking into this there may be found some correlation showing different behaviour due to different voyage purpose or ship type.

4.4 "Available alternatives" (H2.1)

The characteristics here is to find the available new alternatives methods to reduce variance that can be used if available. The findings of how much the baseline can be improved is done by estimating how much can be gained from the suggested solution.

4.4.1 The data to be collected (H1.1.1, H1.1.2/H1.3.1 & H2.1.1, D)

In this section of going from hypotheses to higher level observations, we are looking at which data we need to collect. In the end, the following characteristics to measure, were presented as basis for the "next step" to make a Data collection plan.

4.4.2 The Data collection plan

Before we can start analysing data we a plan in what and how to collect data. The "data collection" step is the third step (third column) out of the first four columns in

Figure 14 "Going from hypothesis to high level observations above. After we have we finished the first two steps, (1) defining the hypotheses and (2) defined what characteristics to measure, we can collect data (3). Later we can start the data analysis (4). Let's look at the creation of a data collection plan.

When making a good data collection plan, we need to make sure the "data to collect" aligns with the "characteristics to measure". In order to do this we may need to clarify what we are looking for by, describing an "area of interest", as shown in the middle column in Table 5 below. After some1 initial ideas and after a couple of iteration rounds we came up with some areas that would be interesting to look into (H1.1, H1.2, H1.3 and H2.1). When this was done the next step was to define the needed data seen in the third column of Table 5 *Area of interest to be explained by collected data* below. In the table we see a short line-up of data characteristics (H1.1, H1.2, H1.3), areas of interest and which data to collect (H.1.1.1, H.1.2/H1.3.1). The table is the result of many iteration processes as shown in Figure 13 above during the data collection process. It shows the results when the data collection process was in progress and had matured.

Data characteristics	Area of interest	Data to collect
H1.1 Variations to arrival ship voyages	Measure the variation of ship arrivals and if there are variation improvements (lower standard deviation) when voyage estimates (ETA) are updated	• ETA and ATA for each voyage and their updates (H1.1.1) •
H1.2 Variations to departure ship voyages	Measure the variation of ship departures and if there are variation improvements (lower standard deviation) when voyage estimates (ETD) are updated	• ETD and ATD for each voyage and their updates (H1.1.1)
H1.1 / H1.2	Total cost of variance	• Direct and/or indirect costs related to variance
H1.3 Ship types and voyage purpose	Looking at voyage purposes and identify patterns. See which ship type are the most frequent visitors in "conventional cargo port".	Ship and voyage purpose for each voyage (H1.3.1)
H2.1 Available alternatives	Which new methods makes the cargo transportation in more profitable.	Researching in the internet for new trends, find theories and tools for variance reduction like Total Quality Management (TQM), JIT, LEAN, A3.
"D" Value and supply chain collaboration	Which collaboration what methods and tools exist, which method and tools can be used.	Methods and tools already existing. New methods and tools available.

Others	Most frequented from/to destinations (In Rogaland and The *Port of Sandnes* and *Sandnes Havneterminal AS*)	Location code of the last registered port (port arriving from) and the next port (port departing for)

Table 5 Area of interest to be explained by collected data

After deciding on collecting ship arrival data containing ETA, ATA, ETD and ATD (H1.1.1), we need to see if that information is available. This is done in *Table 6 Data collection criteria and available data* seen below. It was known that the terminals and ports would have the actual data (ATA, ATD) on this, because they use it to invoice their customers (Ships, agents and others). The estimates data of arrivals (ETA) and departures (ETD) are essential for our calculations of variance. In the step of analysing "Ship Arrival" (H1.1.1.1) we also wanted to analyse if updating estimates during the voyages, would help reduce the uncertainty and deviation to the time the ships actually came or left. The problem soon realised was that the Terminal Operation Systems (TOS) or Port Management Systems (PMS) overwrote the previous stored data, so that we would not see any earlier voyage history data. TOS- or PMS systems would thus not have the information about the first planned time of arrival (The first ETA) which we needed to observe any improvement. We need the estimates and the update data history of each voyage to check these two things (variance and variance by updating estimates).

The next step was to draw up a method of data collection. The data to be collected was defined from "Characteristics to measure" as seen in column in

Figure *14* (H1.1, H1.2 and H1.3). The following description shows how the empirical data was collected.

After defining what data types were to be collected the work then started in which the data were perceived as A or B data. The criteria that a data type should be classified as a "A criterion" was that the data type was absolute necessary and compulsory for the hypothesis testing. "B criteria" were the data which seemed not that important at the time or was known to lack in all known sources of data. In the end the list of possible data sources, data types looked like this.

	A criteria	A criteria	A criteria	A criteria	B criteria	B criteria	B criteria
Data type→ Data source ↓	Voyage update history	Arrival and departure data[4]	Ship type	Voyage purpose	Pilot bookings	Tug bookings	Unique location code
NCA (SSN-N)	Yes	Yes	Yes	Yes	Yes	No	Yes / No
Port of Stavanger (PMS)	No	Yes, but only the last values	Yes	Same as SSN-N	No	No	Yes / No
WestPort (TOS)	No	Yes, but only the last values	Unknown at the time of data collection	Unknown at the time of data collection	Unknown at the time of data collection	Unknown at the time of data collection	No
Port of Sandnes / Sandnes Havneterminal AS (PMS/TOS)	No	Yes, but only actuals	Unknown at the time of data collection	Unknown at the time of data collection	Unknown at the time of data collection	Unknown at the time of data collection	Yes

Table 6 Data collection criteria and available data

When looking at Table 6 above we see that there are several columns containing the text "A criteria". The data sources which did not meet all the "A criterion" were discarded or not collected.

As seen in the figure above the Norwegian Costal Administration (NCA) fulfils all the A criteria (H1.1, H1.2 and H1.3). The data contains the ETA_0 / ETD_0 needed for having reference points to the first "booking" for the rest of the updates (E.g. $ETA_{(1, 2, 3, 4 \ldots n)}$ and $ETD_{(1, 2,3,4 \ldots n)}$) to be "lined up against ". In knowing that the NCA had most of these data, Jarle Hauge who is the Chief Engineer for IT solutions and the development of SafeSeaNet Norway, was contacted and asked if it were possible to get the data needed. The answer was quick and positive and the software supplier Fundator (Terje Hellesvik and Mads Hoel) swiftly provided a huge amount of data containing SSN-N ship arrival and departure

[4] ETA, ATA, ETD, ATD. See also the "Abbreviations" chapter

messages. When writing to Mats Hoel asking about the data sets he said that the picture below shows the connection between the arrival voyage and the departure voyage messages and that *"Ports and EMSA typically operates with Port Calls, whereas the NCA operates with both an arrival voyage and a departure voyage"*. The picture below is adapted from Mats Hoel's picture sent to the author by e-mail.

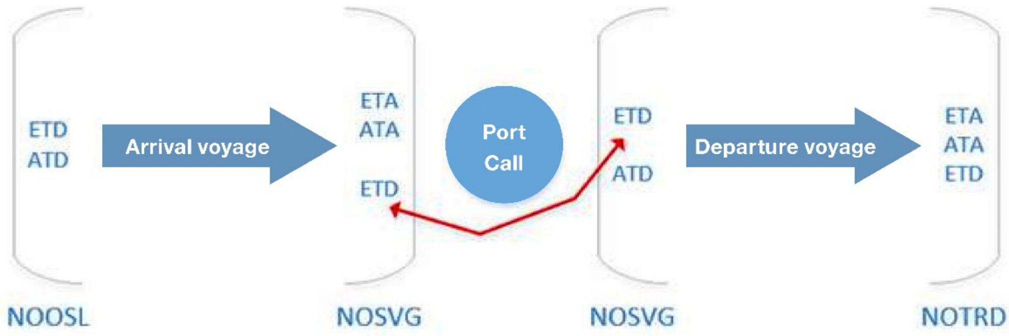


Figure 18 The connection between arrival notifications and departure notifications in SSN-N (Hoel, 2017)

The data of one ship visit comes thus from two voyages, which in combination makes a Port Call. The most important part is the link of the two ETD's ($ETD_{arrival}$ and $ETD_{departure}$) shown with the red arrow connecting them. Each voyage represented by the blue arrows have a unique VoyageID which needs to exist for the data for arrival and departures to be connected and at least one of the voyage data registrations needs to know the VoyageID of the other one. In the case of the data given from NCA the departure voyage had the VoyageID information about the previous arrival. In chapter 4.5 on page 63 how these data was combined is additionally explained.

Some data were also collected in parallel from the container terminal WestPort and the Port of Stavanger, but because these data did not meet all the A criterion and did not contain the update history of the voyage reports they were laid aside. During later interviews with some of the employees in the *Port of Sandnes* and in *Sandnes Havneterminal AS*, it came up that they only saves actuals, multiple persons in the port confirmed this during the various interviews. Because of this we cannot calculate deviations from the *Sandnes Havneterminal AS* data, and thus do not have any other available empirical data for the variation analysis. In not having these empirical data, verification of the SSN-N data has only been available through interviews with the actors described below in chapter 4.4.3. As such the master thesis lacks the "confirmation" of other empirical data.

4.4.3 The data extracted

As a result of the work done above it was easier to see what data needed to be collected. The Data collection plan described in section 4.4.2 above was a valuable tool. Without this data collection method and tools, it could have had been difficult to limit the scope of the master thesis.

Let's first take a look at the empirical data collected, mainly used in Hypothesis (H1) and Later we will also take a look at the data collected when we weight the alternatives for our second hypothesis (H2) before going over to take a look at the data collection plan which led to focusing on which data to collect. The data collection plan is described in chapter 4.4.2 above.

H1 data: After the usage of the first Kaizen step and TQM tools and methods, the final dataset given from the Norwegian Costal Administration (NCA) contained the following data and their intended usage in the data analysis:

- Ship arrivals and departures data (H1.1.1)
    - Rogaland -> Sandnes -> North Jæren -> Rogaland
    - Correlation between late arriving ship and delayed departure
    - Berth stay
    - Scatter diagrams (Variation arrival/departure)
    - Histograms (Notification time)
    - Analysis, delayed hours
- Ship types and voyage purposes (H1.3)
    - Pie charts (Ship types, voyage purposes)

The Terminal infrastructure used (1.1.2) are dependent on which terminal and berth we are looking at. In this master thesis the infrastructure is described of the terminal *Sandnes Havneterminal AS* in the *Port of Sandnes*. The ship types frequenting there are mostly that of conventional cargo (general cargo, bulk, containers) and is described in the context for the whole paper when looking at this type of operations for the whole study (earlier presumptions).

The data given from NCA, containing the SafeSeaNet Norway data was collected through a data collection plan described above. The data given contains data enabling the calculation of the total cost of “delayed or too early arriving ships”. This is shown in the “Data analysis” step later on and enables us to use a method of inductive reasoning to deduce findings in a lower level (Sandnes Havneterminal AS) to conclude on that total variations hours for certain ship types in the terminal looked at, is representative on the levels of “The North Jæren Region” and “Rogaland County” as well using the same calculations and ship types for these.

Criticism

The lack of alternate verification data does not make the data analysis as robust as wished for, where a second source of empirical would have strengthened the master thesis and its verifications. The Norwegian Costal Administration (NCA) and SafeSeaNet Norway is only known available source of historical update data. The ports and terminals should change their tools of data recording, so that such an alternative is available for further studies. By saving all the data and “way points” the actors (terminals and ports) would also have possibility to attach “systems of early warning” or enabling the analysis of historical variation of their visiting ships.

4.5 Data combination

In order to observe results from the data we need to transform and analyse the data. The first step “transforming” the data may best be described as “a data manipulation phase” where the data are put together and aligned according to the Presumptions and assumptions, limitations and constraints set. These are described in chapter 1.8 on page 26 above. Then we are able to perform the second phase which is the data analysis where the experiments are performed to test the hypotheses. We will go through these two steps in the following chapters.

4.5.1 Data manipulation and analysis (H1.1.1.1, H1.1.1.2, H1.1.2.1, H1.1.1.3, H1.1.1.4)

This data took quite a time to get familiar with and also needed a bit of programming in VBA (Virtual Basics for Applications) as the data came in three separate worksheets. The first work sheet contained the ship arrival estimates (ETA_{arr}) and ship arrival actuals (ATA_{arr}), the second worksheet had only the estimated time of departure (ETD_{arr}) from the arrival voyage and the last worksheet contained the departure voyage messages containing estimated ship departure (ETD_{dep}) and actual time of departure (ATD_{dep}).

In the end the tremendous amount of data, needed to be sorted and analysed. The schema described above in

Figure *14 "Going from hypothesis to high level* observations, was then used in the further work where most of the time has been spent on analysing the SSN-N data in column four (H1.1.1.1, H1.1.1.2, H1.1.2.1, H1.1.1.3, H1.1.1.4). The data from NCA was put together by using the logic shown in *Figure 18* on page 61above. After the first results were visible (scatter charts and histograms) the findings from the analyse were discussed with the faculty supervisor Jan Frick and skilled maritime persons, like retired maritime agent Thor Egil Slettebø and Anette Jordal, one of three employees interviewed in *Sandnes Havneterminal AS, as well as* and my colleagues in the Maritime department at the Port of Stavanger. The interviews were used to get a second opinion and if possible, a verification of the findings. Using interviews as verification will never be as strong as verifications by using an empirical verification. Interviews can to some extent confirm findings and lead to deeper insight and new knowledge. By doing data analysis and interviews the new knowledge may lead to the need to make some assumptions, as discussed in chapter 1.8 above. Most of the limitations and constraints found are on the usage and interpretation of the SSN-N data which heightens the uncertainty. This is described in later chapters. The arising uncertainties, data limitations and constraints that came from the preliminary analysis and interviews were taken into account and is discussed in the continued work of the master thesis.

4.6 The first hypothesis (H1)

The first hypothesis is *"New methods can make cargo transportation in North Jæren more profitable"*. Finding new methods to make cargo transportation in North Jæren profitable were done through brainstorming, weighting of alternatives and calculation of the "wasted" hours due to ship arrival and departure variations. The thesis takes a first look at the "waste" in "Sandnes Havneterminal AS", for later to calculate and how the findings there can be used to make a qualified assumption for the total "wasted" hours in the "North Jæren" region and the whole of "Rogaland county" by using inductive reasoning. The SafeSeaNet Norway (SSN-N) data given from the Norwegian Costal Administration (NCA) were used for the visualisation of the deviations and the calculations of the "base line" of total deviation hours, using these tools and methods. The previous findings show that variance should be avoided to have a stable foundation to build upon. The use of TQM and Lean methods and tools, is some of the essential building blocks in reducing waste and is thus implicit one of the supportive tools for the new methods and is also the main tools and methods used in this master thesis. Let's take a look at the new methods and which one should be the preferred one.

4.6.1 The new methods

As earlier seen in the "Ishikawa" / Fishbone diagram in Figure 15, the common cause for unwanted effects ("Muda" / Waste) were that of variance or "Mura" (unevenness). The tools of Lean bases themselves upon Figure 9 Lean Manufactory House and the first layer is "Stability" (Robustness). Without this base layer being stable, "the house" is not built on "solid rock". In worst case this means that the system ("the house") is not able over time, to be sustainable. The variance to the system causes "stress" (overburdened), "unevenness" (variation) and "waste" as described in Figure 12 *Effects of Muda, Mura and Muri* .

A "new" method to be used in the maritime business need "Stability" and reduced variance. As seen in the Kaizen circle in Figure 10, the last step of activities is to have "Standardised Work". The author has thus looked for ways and tools to reduce variance as seen in the weighted options diagram below. The new methods found are

4.6.2 Weighting of alternatives (H2.1.1, H2.1.1.1, H2.1.1.1.1)

During the work the following new methods, or rather propositions on how to reduce variance appeared. Some are merely technical like improving roads or vehicles, and others are more IT technical where data is shared using existing and upcoming standards. By combining standards and technology, there may be a way of reducing variance and waste in the ports and terminals. The author has tried to find new methods for the industry in Rogaland and North Jæren by looking at known methods or solutions that are emerging. The list shown in Table 7 below, shows the brainstorm result after several iterations between H2.1 *Available alternatives*, H2.1.1 *Find rights tools and Methods to detect variation* and H2.1.1.1 *Alternatives that can be implemented within next 0-5 years*, shown in

Figure *14* above. The author has also tried in the weighting to show the "H2.1.1.1.1 Economic gains and market incentives" in the discussions done in the descending descriptions (8-1) after the Figure 19 The weighted alternatives on page 68 below.

The list is the subjective result of the author and should therefore not treated as an absolute truth. This list is a result of continuous improvement and is the result of brainstorming around step four "Hypothesise Solution" in the Kaizen activities (Figure 10, page 35). The alternatives for new methods are first listed up and later described after the weights are added and scores calculated for that later chosen attribute in Figure 19 below.

Alternative:	Description:	Infrastructure / IT tool / Technology
Tracking of goods	Real-time tracking of goods makes better customer awareness and adds value for the whole supply- and value chain in JIT operations world-wide.	Sensors, Transponders/Receivers, algorithm, IT-tools
Information sharing HUB (Ship - Port - Hinterland)	Enables local or national hubs to do more JIT operations in all joints of the supply chain, adding quality and value to the customer.	Transponders/receivers, standards, analytical tools, algorithm, IT-tools
Folding container types	Foldable containers reduce empty space (waste). This may reduce the storage space and have an environmental and cost saving edge over conventional non-foldable containers during "empty" transport.	Technology; foldable containers
Goods HUB's (Physical Internet)	Many Hubs for "short leg" transport, smaller ships and terminals outside the "main sea/land routes"	Infrastructure, algorithms, IT tools
Electrical cars/trailers	Reduce emissions/cost	Super capacitors, super conductors
Railroads	Reduce emissions/cost, faster transport	Infrastructure
Electrical ships	Reduce emissions/cost	Super capacitors, super conductors
Roads	Reduce land based bottle necks	Infrastructure

Table 7 Alternatives for the maritime business

When we look at the list above, we recognise that there is not "easy fix" or solution. Some of the technologies have high costs or would in worst case meet strong protests and have a need for extensive lobbying. (E.g. Building road or railroad in urban areas; taking away living quarters, increasing noise of traffic) Some of the others methods may need longer time to build up and other technology or methods which is not covered may make some of the solutions obsolete. Some of the alternatives may as such never materialize even if they are high up on the list. It is therefore important to continuously check up on new solutions (standards, methods, technology and tools) by the use decision trees, and continuously observations (checks or studies) in an effort to govern risk (both positive and negative risk).

By doing so we need to acknowledge that even a good decision may have a bad outcome and vice versa.

The next step starts by giving the different alternatives some attributes which can be weighted by importance. After some consideration the following attributes (Orange cells in 1st row) and their weights (Yellow cells 2nd row) and how they influence the total score (+/-) were created. An attribute with negative number (-) is rated as having negative impact. An attribute with a low weight (E.g. Value = 1) means that it is not rated as important as an attribute which have a higher weighting (E.g. Value = 5), for negative number it is the opposite where bigger negatives are having bigger negative effects.

Investment cost (-)	Technology readiness (+)	Lower Waiting times Ship side (+)	Lower Waiting times Port side (+)	Lower Total Turnaround Time (+)
-5	4	3	3	3
Start-up costs	Within 0-5 years	Reduce variance	Reduce variance	Reduce length of berth stay

Increased Sales / Customer Satisfaction (+)	Positive Environmental Impact (+)	Better Resource utilization (+)	Negative Risk (-)
5	3	5	-5
Better quality of service	Reduced emissions	Fewer non-productive hours	[…] due to loss of reputation and good will. Risk of more accidents due to technology or increased use.

Table 8 Attributes and weights

As pointed out above the weights are given by the author from a subjective view. This means that the neither attributes, nor their weights given to the alternatives are absolute certainties. When looked upon again in 5 years or by someone else tomorrow, the perceptions and technology may be different. This should be treated as the subjective opinion of the author at the time and place of writing the master thesis and may well be refuted in the future by readers or the author if new information or methods are available or more important attributes shows up. This means that even if the author tries to be as objective as possible, the list is still a result of subjective “best guesses” of a “brain storm”.

Below we can see the list of weighted priorities after the scores have been calculated and sorted by size. The end result is a list of scores which could tell us which projects/methods should be prioritized and its order, out of the different alternatives listed in Table 7 above and Figure 19 below.

	Alternatives/Attributes	Investment cost (-)	Technology readiness (+)	Lower Waiting times Ship side (+)	Lower Waiting times Port side (+)	Lower Total Turnaround Time (+)	Increased Sales / Customer Satisfaction (+)	Positive Environmental Impact (+)	Better Resource utilization (+)	Negative Risk (-)	SCORE
Ranking	Weights	-5	4	3	3	3	5	3	5	-5	
1	Information sharing HUB (Ship - Port - Hinterland)	-15	20	15	15	15	25	15	25	-10	105
2	Tracking of goods in realtime	-20	16	15	15	15	25	12	25	-10	93
3	Folding container types	-10	12	12	12	12	20	15	20	-15	78
4	Goods HUB's (Physical Internet)	-20	8	12	12	12	20	12	15	-10	61
5	Electrical cars/trailers	-10	16	6	6	6	10	15	10	-10	49
6	Railroads	-25	20	9	9	9	15	15	10	-15	47
7	Electrical ships	-15	12	6	6	6	10	15	10	-5	45
8	Roads	-25	20	9	9	9	15	6	10	-15	38

Figure 19 The weighted alternatives

The scores at the far right are the sums of each horizontal ranking row. This sum is a representation of what the author seem is the most sustainable "new methods" available at present. Each partial score is given by multiplying the "Weights" (yellow cells) with the authors scores given for each attribute. The figure does not show the calculations, but the potential scores would range from 1 (1 x 1) to 25 (5x5) where the plus (+) or minus (-) would have given the cells score to be added to the line total.

The values given before adding the attribute's "Weight" ranges from 1 to 5. Where 1 is having a low (positive or negative) impact and 5 have a big (positive or negative) impact. The values given between 2 and 4 are representing more of a middle value. By "back-tracking" it is possible to calculate the score given by the author. This is done by dividing the individual cell value by the columns weight (yellow cell value). E.g. For the first column "Investment cost (-)" we can divide the first cell of "Information sharing HUB (Ship-Port-Hinterland)" by the value -5 which is the "Weights" given for this column. The result is 3, which mean that it according to the author has a "medium" investment cost.

The first four ranked alternatives need a bit of explaining as they are should not be so obvious without a deeper explanation. Let's go through all eight alternatives and start from the bottom and make the way up to number one.

8. Building Roads - Score 38 (H2.1.1.1)

Building roads may seem a good solution, but they do not score well in the total scores. They have high investment costs, and a mid-level impact on waiting times for the ports and ships as the "hinterland" road net in Rogaland and North Jæren usually do not usually have queue problems outside rush hours. The positive effects are of course that the lorry or truck drivers (the customers of the roads) have a better condition on the roads. The negative risk comes from the increase in cars and pollution, which may in turn cause more accidents. The building of roads is as such not a solution to be looked at first and it does not help that much. It is also a very costly undertaking in urban areas where people live and may have to be resettled, with the cost that follows. Instead of building roads there may be a more pressing need to look at the 3 M's shown in Figure 12 on page 37 and how to reduce the waste described there.

7. Electrical ships / 5. Electrical cars/trailers - Score 45 & 49 (H2.1.1.1)

There are much talk these days about autonomic self-driving cars, busses, trucks, ships or air planes. This is expected to come in the future, but seen in a 0-5 years' perspective the author only believe that small scale testing is all that will be done even if there are big contributions from big actors. But what will come is the electrification of most of these means of transportation, except perhaps of the airplanes. The big problem is weight and transport range before the need of refuelling. The cost of batteries may not be that big, but for now the weight-range and thus the cost-benefit ratio seems in a disfavour of conventional fuel engines. This may change if the miniaturisation of capacitors (batteries) makes them lighter. Another aspect of electrical vehicles or ships are that they need the energy from somewhere. At present there are being built several low scale "refuel" sites for ships and vehicles. Some of the challenges are that there would be a need of more places to fill up electricity, the power grid would have act as if it were *"one giant copper plate"* (Aengenvoort and Sämisch, 2016) to have the full flexibility that ships or trucks have who can bunker fuel at or close the smallest ports or terminals. A ship which does not have enough fuel out at sea, can even bunker from special "bunkering ships" with no need for land-based infrastructure. As seen in the matrix both ships and trailers have the possibility to either new invest or refurbish to electrical propulsion, many ships already have electrical engines, but are delivered the electricity from heavy or lighter oil driven generators. The costs are low to medium size to upgrade to batteries, but as said earlier at the cost of lower operational range and may only be applicable for the short-sea shipping liners. Refurbishing will have a positive environmental on the renewable fuels side, but have uncertain foot print when coming to energy used for production and the end of life problem with disposal of old batteries. In addition, the ships and trucks are going to do the same task a before, there is not going to be any changes to punctuality in arriving or departing a port or terminal. This is why the scores are not that good for these “new methods”.

6. Building Railroads - Score 47 (H2.1.1.1)

The trains are as we know limited to their tracks. The location of the tracks is thus more important than for many other types of transport which may use paved road or roads of other consistency, as well as the possibility of discharging or loading goods almost everywhere there is space without causing congestion by blocking the way of transport. A train does not have the luxury of being able to load and unload goods almost everywhere. The advantage is that goods trains and train terminals handling goods are highly standardised. Another advantage is that the railroad mostly connects industries of importance to each other, major and smaller intermodal hubs are connected where the goods is distributed to the customers and the end users. It is therefore very important to have good access to these train station hubs, for all goods transporters, if the capacity and quality of the train services are right. It is also mostly seen upon as an environmental friendly mode of transport, using electricity, even if there are trains in some regions where trains are using diesel engines. The building of a railroad is costly, therefore this “new method” gets the lowest possible score on investment cost. The building of railroads like for normal roads may have negative impact in that is generates more traffic at the hubs, therefore it does not score more than a middle score of 15 in the “Positive Environmental Impact” column. It also does not affect the waiting times for ships or terminals for the same reasons as for the “8. Building roads” option.

4. Goods HUB’s, The physical Internet-PI - Score 61 (H2.1.1.1)

The Physical internet is the idea of using the knowledge and methods of transport of internet packages in the physical world where goods are packed in modules which can be build and re-built like Lego bricks at each hub. The idea is that short sea shipping or short road transports are more efficient (minimum waste) than long haul transport. The good side effect is that the truck driver would work from 9am till 16pm and drive home each afternoon to his family. Thus having a healthier family life than if he/she were to spend the night away from home. It is also a sustainable way because the legs are more predictable between local hubs and the "main high way" of PI. The problem is that this method is not as mature as we could hope for. The project is fully mature in "2050" (ALICE, 2018), which is 32 years in the future! This also means that even when it has big potential and looks promising, it is not within the scope of this master thesis of finding solutions that are ready to be implemented between 0-5 years.

3. Folding container types - Score 78 (H2.1.1.1)

The first that strikes the onlooker when looking at you tube movies in fast real time or even in fast forward captions, is that it takes time to fold or unfold a foldable container. In addition, there seems to be a need for several operators doing synchronised work to do this. The technology is thus not as mature as one would have hoped for just now. But this will most likely improve as the need for space and fuel saving technologies arise. When looking at the scores in Figure 19 above we see the medium score for "Technology readiness". In an interview with retired Ship agent Thor Egil Slettebø, the trend is that the containers used are being made bigger. The usage of 40+ feet type containers is according to him rising. This makes the need for better solutions using fewer or same number of "folding operators" even bigger. The author is thus uncertain of the environmental impact if these containers are no able or too complicated to fold. The score on the "Positive Environmental Impact" and "Better Resource utilization" have thus not gotten a maximum of 25, but has gotten a score of 15 and 20.

2. Tracking of goods in real time - Score 93 (H2.1.1.1)

There has been tracking systems of goods on the market for some time, where bar codes or similar of the individual parcels are scanned at given points in the logistic flow. The individual parcel or package is then stuffed into boxes, pallets or containers for further transport. These again have their own markings, bar codes or similar which in turn are scanned at their check points in ware houses, at terminals or at the end destination. These are then again shipped by trucks, train, airplanes or ships which can be tracked by AIS-/GPS-systems. Unfortunately, the links from ship tracking down to the individuals parcel or item has not fully been integrated into the supply and value chain in Rogaland as far as the author could discover from interviews or internet searches. When interviewing employees at WestPort they say that they only know which containers are coming not the contents in them. This means that even if all containers are scanned when stuffed and loaded on board a ship or

truck, the content inside is not relayed to the terminals. The terminal only sees the numbers of containers and their markings given at the warehouse or terminal of origin. This is as the author sees it a supply chain which lacks a lot of information downstream (H1.3.1.1), which in turn also may be a problem for big actors like Amazon and Alibaba who should have a full coverage of tracking between the container stuffing at the origin and the destination where the containers are unstuffed. It would be, as the author sees it, in their interest to ensure that by sharing their parcel numbers and “meta data” are connected to the container in which they sit. In turn the all the actors in the supply chain should have the “number of the container”, on which “vessel or transport” the container sits and by this be able to track in real time all movements of the cargo. By cargo is meant all from the individual cargo (highest possible granularity) up to the container level (lower granularity). This should be a task for all the freight forwarders, who should distribute these tracking data with the help of their “supply chain networks” like in the example of Figure 16 Simplified supply chain - India to Norway – Part I and Figure 17 Simplified supply chain - India to Norway – Part II on pages 54 and 55. Seen from the terminal side which is a part of this “supply chain network” such data may increase the knowledge of when and what type of goods is arriving. It should make it easier to accommodate JIT operations by using the new knowledge to stack and store the containers in a better way, as well as being able to prioritize the stuffing/un-stuffing. A bi-product of having more data is that one can analyse the historical data and thus facilitate their services in alignment to the customer needs of quality of service and cargo handling punctuality. The freight liners and freight forwarders like MAERSK and Kuehne & Nagel, should be aware of the possibilities that lays here to optimize and improve services to their customers.
When coming to the scores for the method of “Tracking of goods in real time” it gets a big plus for “Better Resource Utilization” and “Increased Sales / Customer Satisfaction”. The only big drawbacks are the investment costs, in addition there may be an increase of transport having negative environmental impact and increased risk of accidents (negative risk). In addition, the technology is still not as mature as it should be, but this is certainly going to change over the next couple of years. The method as such is therefore possible to implement, but has a cost connected to it which may be substantial when looking at all the actors in even a simplified supply chain (see 54Figure 16 Simplified supply chain - India to Norway – Part I on pages 54 and 55). It therefore falls short of the “front runner” method of “Information sharing HUB (Ship - Port - Hinterland)” described below.

1. Information sharing HUB, Ship - Port - Hinterland - Score 105 (H2.1.1.1)

As seen in Figure 9 Lean Manufactory House and described in chapter 4.1.1 "Ishikawa" / Fishbone diagram: Cause – Effect analysis, the main issue for operations at terminals and in ports are the variance of goods arriving, either by ship or trucks. The master thesis has not calculated the hinterland effects, but has calculated the total numbers of man hours spent on either waiting or mobilizing earlier because the ships are coming different than their estimated time of arrival (ETA) or leaving different than their estimated time of departure (ETD). This is done when we look at the case of "Sandnes Havneterminal AS". When looking at ship arrivals there are a lot of factors playing in on why the ships arrives different than scheduled. There are many factors for early or late arrivals or departures and to list them all would be an almost impossible task, therefore only a few are listed up below:

- Weather: A ship may have to take a detour due to weather conditions or sea line "congestion".
- Knowledge: The ship may never have been in the area before and are therefore slowing down its speed
- Sequential effects: Wait for the pilot, waiting for crew (crew change), late cargo arriving at last port.
- The port or cargo is not ready: The port or cargo is not ready, delayed ship at destination blocks the berth.
- Border control: The ship has to be cleared before entering the port, or before leaving the port.
- Customs control: Ship or crew has to undergo control.
- Breakdowns: To ship, machines or other equipment preventing the JIT cargo operations.

As said earlier, the master thesis only looks at the arrivals of ships and not the arrivals from the hinterland of trucks or other services and goods. The lack of information and the additional uncertainties of the above mentioned factors adds uncertainty if not shared with all stake holders in a port call. This uncertainty in turn directly affects the punctuality and precision of when ships are arriving and thus creates variation to arrival and departure times, which then spread to the terminal and downstream (H1.3.2.1) value chain. The vibrational effect is most likely bigger downstream where the "capillary" in the system are reacting individually and more or less uncoordinated without the right management, methods and tools. But for now as said let us take a look upon the ship – terminal interaction. The scores given in Figure 19 The weighted alternatives above starts up with the "Investment cost" which is placed at a mid-level, it is not as expensive as many of the other solutions as there are not a need for physical investments other than new servers and space to keep them, these can be built anywhere on existing locations or hired from external actors. In difference from the method of "2. Tracking of goods in real-time", most of the terminals or ports are already using a centralised "Single sign on" system, the SafeSeaNet Norway (SSN-N), where they subscribe (one-way information) ship information's and estimates of arrivals and departures. As such there is a platform that can be further developed to include other actors. The uncertainty is if the Norwegian Costal Administration can undertake such a big task for regions as Rogaland or for the whole country as such, or if the ports and terminals need to invest in a new centralised system. One of the major advantages by having a centralised system is that all the actors must align with standards for communication like they already do in the SSN-N and by using other standards like the PortCDM's "Port Call Message Format". PortCDM stands for "Port Collaborative Decision Making", and is a way to use *"the digitisation of time stamp information between port actors involved in the same port call."* (Lind and Haraldson, 2016) and is a new method of sharing stakeholder information. The time stamps are providing important information about the actor's intentions in real time and can therefore help in optimizing port calls bot at sea and on land with the goal of creating JIT operations. The standard is *"Highly inspired by the airport CDM Council"* and has its own international *"[…] PortCDM Council"* in order to *"establish the necessary overarching guidelines, processes and procedures to make STM and its PortCDM a successful international concept to improve maritime transport in terms of port operations and ports interaction with ships."* (Lind and Bergmann, 2017). The standard is at present being validated by the EU and final results are expected be available by the end of year 2018. This means that one within a 0 to 5-year period there is the possibility to roll out this standard for all actors in the ports and open it up for the ships to use, in such a manner that all actors participating are getting the time stamps, hopefully by using a national system like SSN-N or by building up a central and database for the actors by private investors. The new method of making an "Information sharing HUB", thus needs backing from not only government organs, or investors but also the local community and their actors needs to be involved like one of the main principles of both TQM and Lean to look at all functions and involve all levels of the supply chain. There are thus uncertainties connected to how such a system and HUB should be implemented and its cost. The "Negative risk" column value is rated by the author to have a low to medium score as this also may increase local traffic both at sea and in and out of the terminals if the new method can create new or more cargo transport in the region (Hypothesis 2).

The big differences to “Tracking of goods in real-time” is according to the authors opinion that the “Technology readiness” is greater and it has a slight advantage in “Positive Environmental Impact” as it allows “right steaming” for all the actors and allows JIT operations at the local level when financed (H2.1.1.2 / D), build and implemented correctly into the Port Management System’s (PMS) and the Terminal Operating System (TOS) as well as to other actors and stakeholders in the whole supply chain (see D: Value and supply chain collaboration in

Figure *14*). The preferred new method according to the methods and findings made above is that of the “Information sharing HUB, Ship - Port – Hinterland” which involves all the actors in the supply chain, when the implementation is invested in and supported in the right way from all the actors in the maritime business. The idea of information sharing to get the latest information to act upon is as such the mentioned new method.

Criticism

The list of “New methods” shown in Figure 19 The weighted alternatives above is not made by asking the maritime business as a whole. It is a product of the author whish has to be treated as such. It may that these methods are needed by the maritime cluster, but it may also be that they do not have the need or do not see the solutions as the most critical tasks to be solved at present. The author has thus limitations in knowing other aspects which may be more important at present. The reader should be aware of this and the uncertainties that this implies, and the uncertainties that follows from this.

4.6.3 Kaizen - Make problems visible

The wished for yields is in the first hypothesis (H1) is to increase the profits for the ports and terminals and gain a competitive advantage in the maritime business in Rogaland, North Jæren and at *Sandnes Havneterminal AS* (NOSAS). In step one of the Kaizen circle, is “Make Problems Visible”. We need tools and methods to visualise, by using the theory of TQM and Lean, tools like “Scatter chart”, “histograms” and tables, we can “make problems visible”. In this master the tools mentioned are used to visualise and calculate the variance of ships arriving to *Sandnes Havneterminal AS*, the North Jæren region and the whole of Rogaland county. The visualisations and calculative findings in each “case” are described in the following sections.

4.6.4 Visualising Arrival times and Cost

The case of "*Sandnes Havneterminal AS*" is the basis for using an inductive reasoning and to the basis for a "best estimate" of what the total man hours of similar ports, ships and terminals in North Jæren region or the Rogaland county are. The results should as such be treated as estimates and not as the single truth.

When looking at the conventional cargo operations at the terminal, *Sandnes Havneterminal AS*, in the *Port of Sandnes*, the data analysis is limited to the ship types that is mostly used in those type of operations. Therefore, the study only looks at observations and notifications made by ship types of "General Cargo Ship", "Ro-ro Cargo Ship", "Refrigerated Cargo Ship", "Palletised Cargo Ship" and "Container ship". Ship types uniquely transporting "Dry bulk" and "Wet bulk" ships are as such also not included in the studies.

As described in *The Data collection plan* in chapter 4.4.2 and the *Presumptions and assumptions, limitations and constraints* chapter 1.8, in order to be able to calculate berth arrival and departure deviations (Δh), we need estimates (ETA, ETD) and actuals (ATA, ATD). Therefore, the data set used in analysing the ship arrivals and departures in Rogaland has been collected from the Norwegian Coastal Administration (NCA), which has a National Single Window, SafeSeaNet Norway(SSN-N). SSN-N is used by ships for reporting their compulsory arrival and departure information's, like estimates of arrivals and departures. There are other sources of data, like each individual terminals TOS (Terminal Operating System) and the port's PMS (Port Management System), but the SSN-N data has the of advantage keeping history of estimate updates and their reporting time (time stamp) shown as the x-values in *Figure 20* and *Figure 21* below.

The Rogaland data set

The SSN-N data contains 163.507 voyage registrations and updates to 76.069 unique voyages arriving Rogaland county from 1st of January 2014 until 24th of October 2017. Of these there are 36.548 arrival registrations and 30.649 departure registrations which contains both contain actuals and estimates. The scatter plot below shows how all of the "valid" notifications in SSN-N containing both estimates and actuals are when we look at the raw-data.

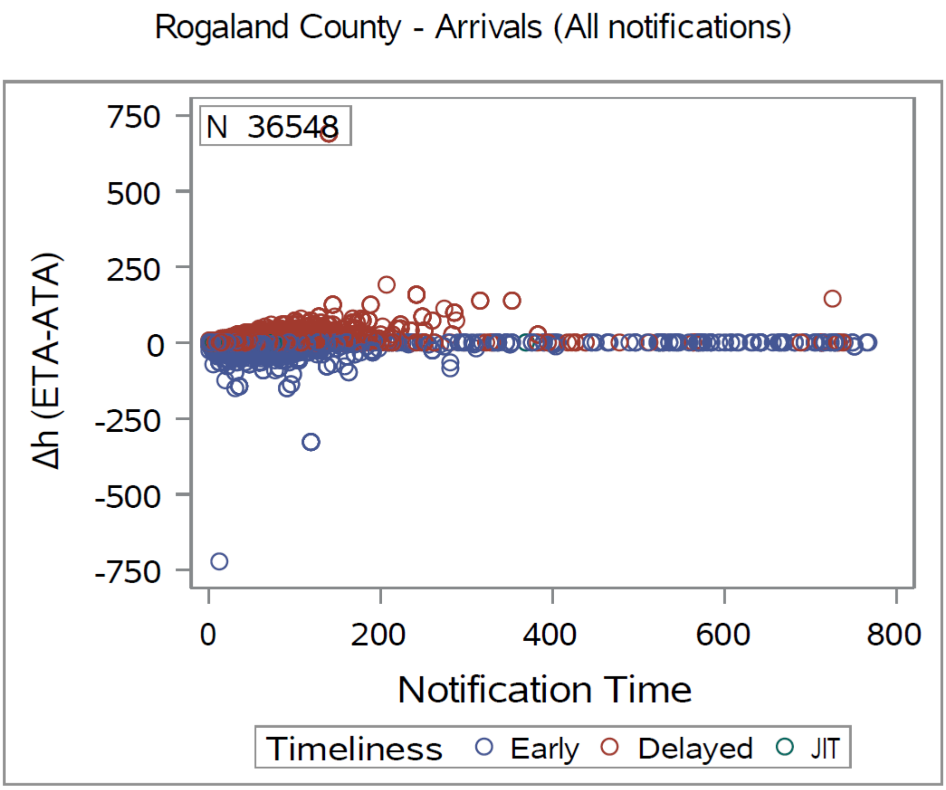


Figure 20 All arrival notifications (SSN-N)

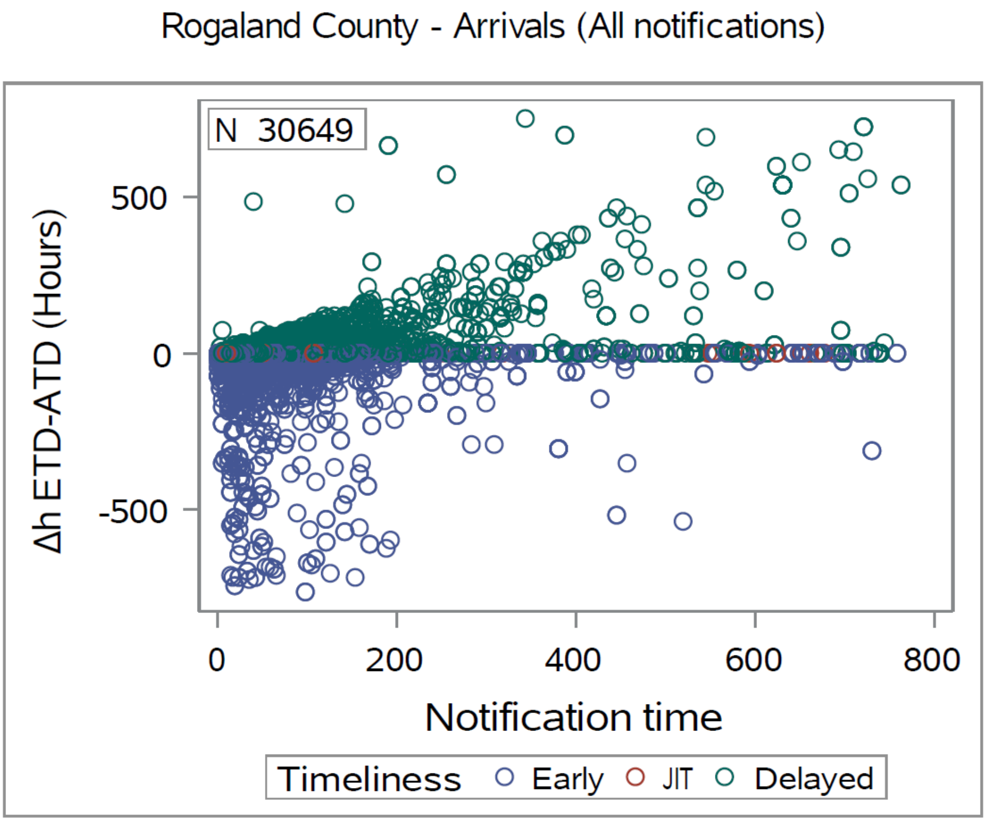


Figure 21 All departure notifications (SSN-N)

In the two pictures above we look at all registrations and updates for all ships that have registered their voyages in SSN-N. As we can see there are a lot of notifications with the departures having 5.899 fewer notifications. We also observe that there are different circle colours which represents if the ships are arriving earlier (Early) or later (Delayed) at the terminals. In the arrival figure (Figure 20) we cannot recognise any Just-In-Time (JIT) arrivals due to the high density of the scatter plot circles. In the departure figure (Figure 21) we can just about see a couple of red circles which represents them in that figure, but they quite hidden among the majority of non-JIT departures. Whereas the spread for the arrivals seems to be within +/- 250 hours of deviation, the spread for the departures are in a range that exceeds +/- 500. This observation showing that departures have around twice the spread, indicates that the arrival time is more predictable than the departure time.

From these two scatter plots and the data that originated them we are going to make new scatter diagrams and diagrams to calculate the total sum of deviation hours in *Sandnes Havneterminal AS* (*Port of Sandnes*) and try to calculate the direct cost of man hours. In turn we want to use the method to do calculations on the whole of Rogaland county and the North Jæren Region by choosing the most frequent ship types visiting *Sandnes Havneterminal AS* and look at them in the two mentioned areas (North Jæren is the region where the *Port of Sandnes* is situated in. The North Jæren region is in turn a part of the whole of Rogaland County).

The reference point of observations (A in

Figure *14*)

Due to the many updates done to each voyage (VoyageID), we need to set a reference point of what to look at when analysing the data. The author has after some consideration choose to use only the first registrations as the reference point of measuring the estimates deviation from the actual times. This is because this is the first message (ETA_0/ETD_0) that is the most important message for planning berth operations. If the it is later updated (ETA_{0+n}/ETD_{0+n}); the port or terminal are always rearranging according to this first notification/registration.

We will later discuss how filters to the timeline and extreme values will reduce the observations even more and also help on interpreting the observations, bus also increase the uncertainties. In the verification of hypothesis two (H2), we will add the observations back and look at if updating the estimates of arrivals (ETA_{0+n}) or departures (ETA_{0+n}) can help in

JIT operations at the terminals. The scatter Plots below shows how the situation is when we have removed the "update" messages.

ETA$_0$ arrivals Rogaland county:

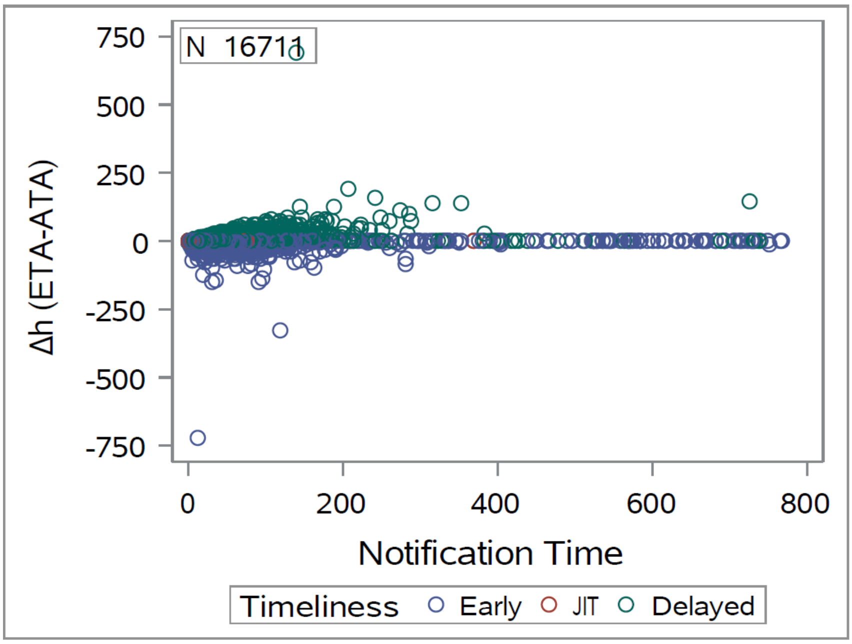


Figure 22 Arrivals Rogaland ETA$_0$ notifications

ETD0 departures Rogaland county:

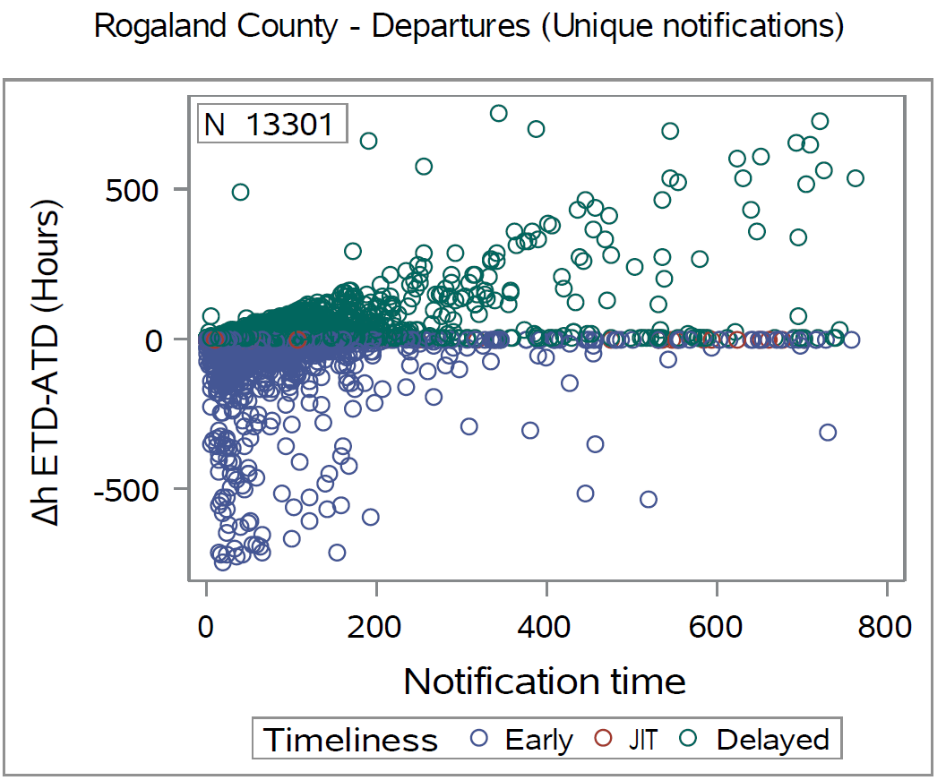


Figure 23 Departures Rogaland ETD₀ notifications

We see that in both the figures that the spread and density have been reduced. The number of observations for the arrival notifications have dropped to 16711 unique ETA_0 messages and the observations of departures have decreased to 13301 unique ETD_0 messages. In order to calculate the deviation for each ship we need these two "zero" estimates as reference point to calculate the deviation from.

The ship types chosen for the further study

By looking at the voyage purposes in the *Port of Sandnes* (NOSAS), the goal is to derive if there are much operations other than cargo operations, the goal is to see if its Terminal is representative for a conventional cargo operating terminal. To be able to observe this we need to remove duplicates, as done above, so that registrations and updates to voyages does not count for more than once per unique VoyageID. The ships arriving are the same ships departing, so that it is only the arrival messages that are looked upon. The total observations of unique voyages/ship visits numbers to 481. We also want to see which types of ships are visiting the terminal. The result can be seen in figures Figure 24 and Figure 25 below.

Voyage purpose NOSAS:

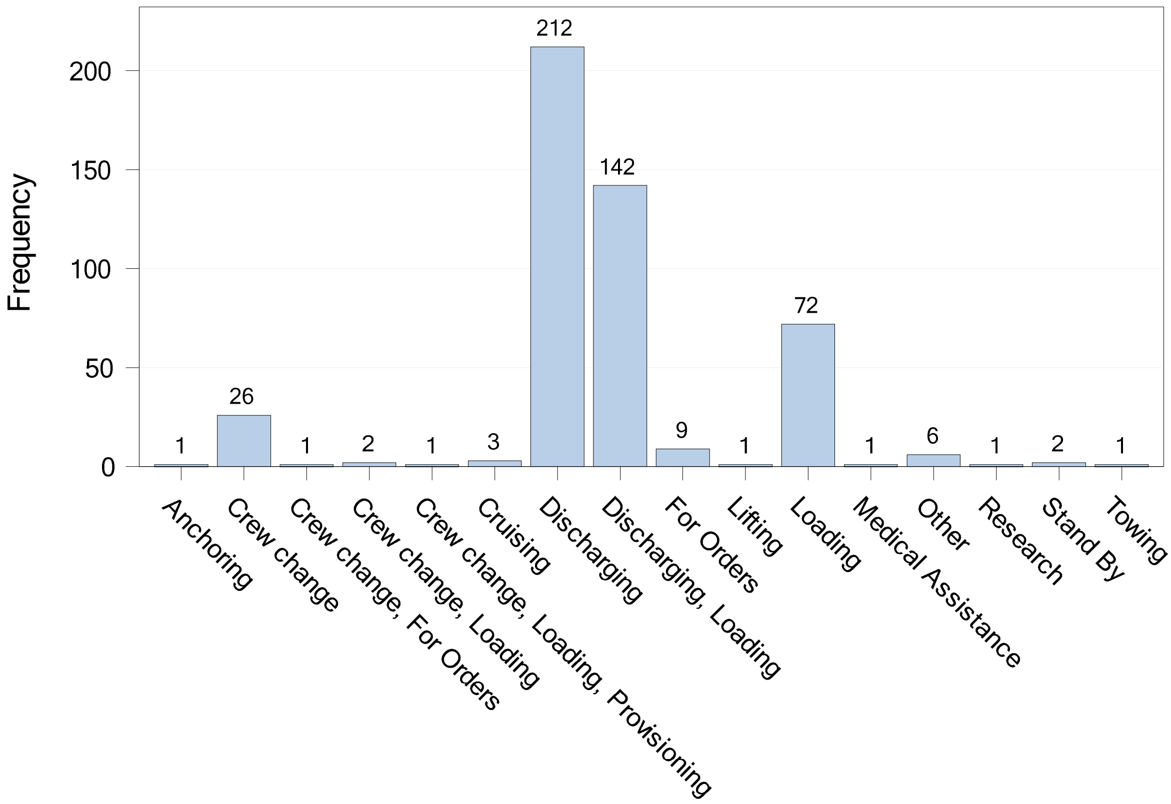


Figure 24 Voyage purposes for arriving ships NOSAS

From Figure 24 Voyage purposes for arriving ships NOSAS we see that the three most frequent purposes are that of Discharging (212), Discharging, Loading (142) and Loading (72) which in total are 426 voyages out of 481 (88.57%). The other purposed counts up to 54 instances (11.43%). Note that the author has chosen to not exclude ships based on their voyage purpose due to the fact that ships arriving the *Sandnes Havneterminal AS* according to Anette Jordal (Sandnes Havneterminal AS) have to follow the compulsory regime of taking linesmen at arrival which ranges from one to two linesmen dependent on ship size and that most ships do some kind of "cargo operations". The most common occurrence is to use one linesmen, and the lines men are provided by the terminal and not externals. By choosing not to do any filtering by voyage purpose, the uncertainties increase around the later usage of a "ship type" filter by simulate "similar terminal" conditions where other ship types are removed. As we see the port and terminal in Sandnes do have other voyage purposes than only cargo handling and we need to be aware of this when we potentially "drag" these voyage purposes with us that do not have anything to do with cargo handling, which is what we want to do. Therefore, in future studies, there is a need for looking more into what not filtering on voyage types and thus what figures including other voyage types than the three major ones identified may pose of uncertainty.

Ship types visiting NOSAS:

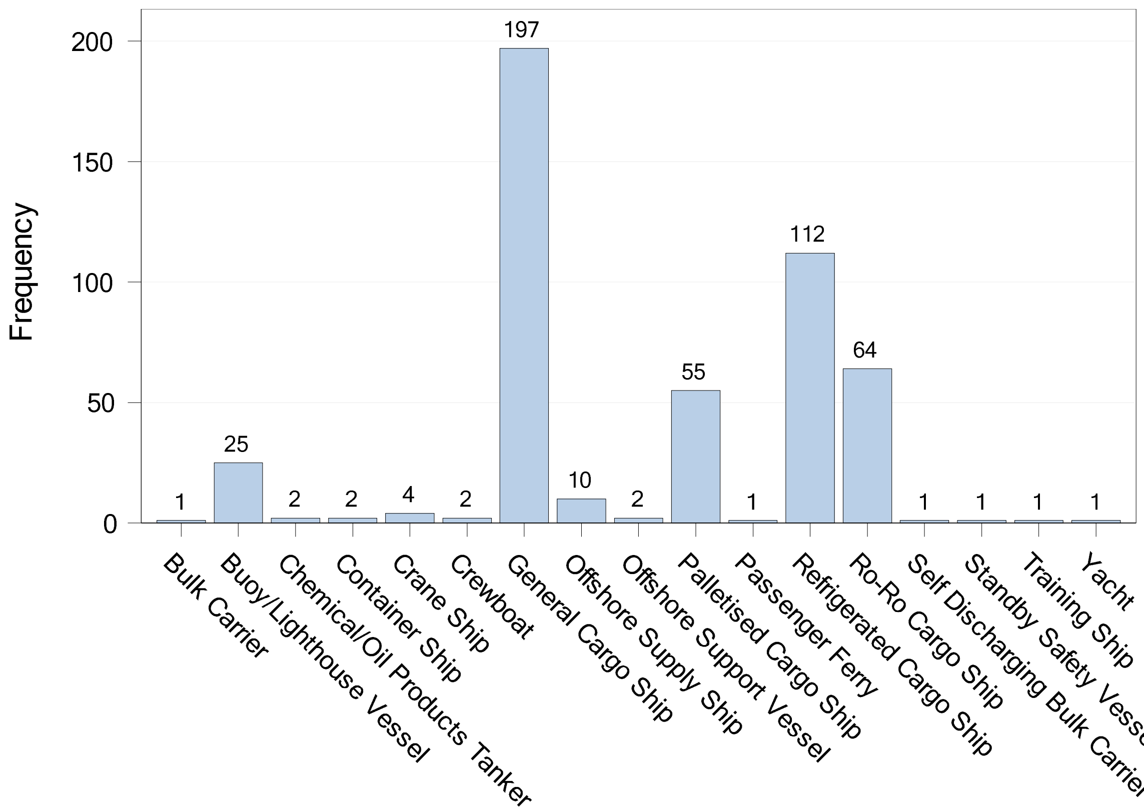


Figure 25 Ship types arriving NOSAS

In the second Figure 25 Ship types arriving NOSAS) we see that the four to ship types are that of "General Cargo Ship" (197), "Refrigerated Cargo Ship" (112), "Ro-Ro Cargo Ship" (64) and "Palletised Cargo Ship" (55). These are the main ship types coming to *Sandnes Havneterminal AS* and is therefore the ship types which will act as a filter for estimating the total hours of variance in *Sandnes Havneterminal AS*, Rogaland county and the North Jæren region. As said above, there is not applied a filter based on voyage purpose and it is the same ships doing all the voyage purposes mentioned. This means that the ship types may have other voyage purposes than that of cargo operations even if the main purpose is something else. In addition, in the further study the ship type "Container Ship" is added due to that they are also doing "conventional" cargo operations with cranes, trucks and so on as described (H1.3.1) used by the *Sandnes Havneterminal AS* in chapter 1.5. Ships transporting "dry"- or "wet"-bulk are not included due to the fact that they are few in numbers in Sandnes and that some of the chosen ship types like "General Cargo Ships" also can carry bulk. This excludes some of the ship types doing general cargo operations in the form of bulk, but due to the fact that there is only one ship type and one occurrence of "Self Discharging Bulk Carrier", the author assumes this to have some impact on the generalisation on the general result due to this few numbers of such specialised ships visiting the *Port of Sandnes*, that could be of greater importance in other places. Ship types uniquely transporting “Dry bulk” and “Wet bulk” ships are thus not included in the studies. In hindsight the filter should have been set on combining both ship types and voyage purposes and may be an improvement in future studies, by increasing the number of ship types and instances to look at.

Applying a “notification time” and “extreme values” filter

After the discussion with Thor Egil Slettebø and Dag Matre as described earlier in the Presumptions and assumptions, limitations and constraints in chapter 1.8, the author made some adjustments and filtered out the estimated values of arrival (ETA) that were made earlier than 24 hours of the actual arrival (ATA), as they are mere guesses. In addition, for both the arrival and departure messages the extreme values above +/- 96 hours of deviance have been filtered way as they are “noise” in the picture we want to look at and are the ones that are needed to look into regardless of if they are “false or correct” notifications. By using the new method of “Information sharing HUB (Ship - Port - Hinterland)” found to be the best method in chapter 4.6.1.

For the departures the timeline is extends to include the registrations of ETD_0 that occur in the length of an average berth stay plus 24 hours earlier. An average berth stay is calculated by using the difference between ATA and ATD, thus only the VoyageID having actual time of arrival (ATA) and actual time of departure (ATD) are used for this calculation. This again increases the uncertainties of how long a berth stay is as we do not have all the data which on an optimal case would give us this. By calculation the average berth visits of all ship types going to all locations in Rogaland is 18.2 hours, but is rounded down to 18 hours. This means that we look at the ETD_0 registrations coming in up to 42 hours (18h + 24h) before the actual time of departure (ATD). This method may not pick up all the first registrations of departure, as there are ships which may have shorter or longer berth stays that then is not a part of the data set any more. But it is far better than looking at the first departure registrations in the arrival message which may not be registered with the method used with the arrival notifications. The timeline for observations of 42 hours prior to departure is also used for the *Port of Sandnes* case. This method may be false used upon *Sandnes Havneterminal AS*, due to the fact that the terminal is so specialised. Again this adds uncertainties due to the fact that all ship types in Rogaland has been used for calculating the average, and an average may not include relevant observations. And a last critic to the method is that this average may not be representative for all terminals as they are different when using such an inductive method.

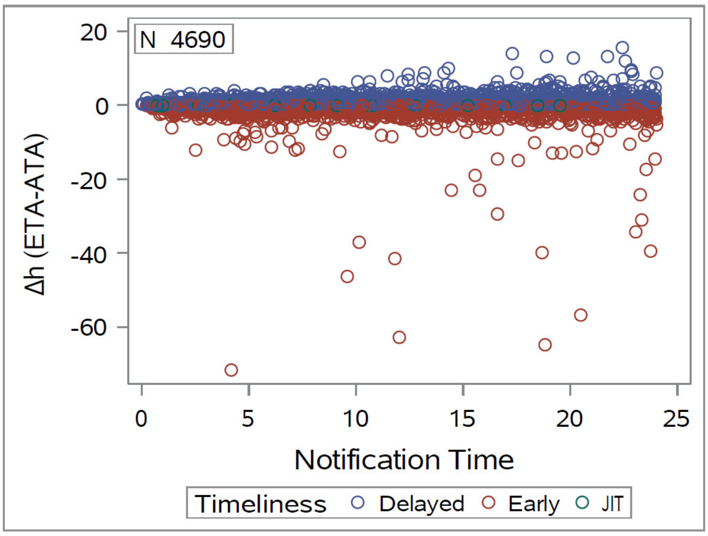


Figure 26 Arrivals Rogaland (ETA_0) 24 hour filter

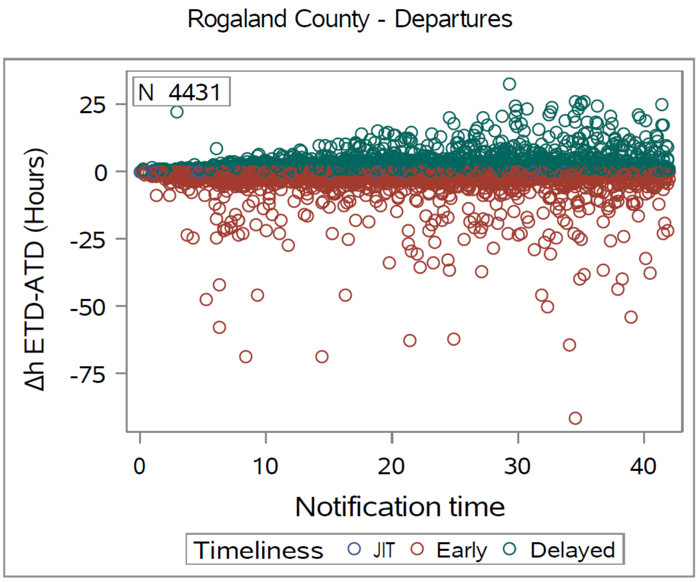


Figure 27 Departures Rogaland (ETD_0) 42 hour filter

After these changes are implemented the picture of both Rogaland and *Sandnes Havneterminal AS*'s arrivals and departures look different. The ETA_0 and ETD_0 observation numbers are reduced from the previous scatter plots and they are "Shorter in length" and seems to have more compact observations. The spread of the observations is thus smaller, where the departure observations seems to have a bit more spread than the arrival observations. In Scatter plot Arrivals and Scatter plots Departures, the arrival and departure scatter charts for North Jæren and *Sandnes Havneterminal AS* (NOSAS) and the other unlocodes in North Jæren are found. They show the result after the data in the steps above are filtered away and some of these scatter plots are used in the master thesis leading up to the calculations of deviation to *Sandnes Havneterminal AS*, The North Jæren region and Rogaland County.

The inductive path

The result so far has been drawn from analysing the whole *Rogaland county* data set and go down to the terminal in *Port of Sandnes, Sandnes Havneterminal AS,* where the ship types to analyse were chosen and used as a filter for the *Rogaland county.* This is thus an inductive method from the ship types most used in a terminal (Sandnes Havneterminal AS) that mostly do *"conventional cargo operations"* and then use these fewer observations to generalise from "few to all" observations in Rogaland county for these ship types for later use in the *Sandnes Havneterminal AS* case and North Jæren area observations. Let's start with presenting the findings for *Sandnes Havneterminal AS* using the preliminary finding from the "inductive path" described before using filters applied on the data described in the previous sections of chapter 4.6.4. Then we will move up to do the same as described above for the whole of Rogaland county and then down to the North Jæren doing the same methods and calculations.

4.6.5 "Sandnes Havneterminal AS" (Case) – Arrival times and cost

As stated earlier in chapter 1.5 the *Port of Sandnes* and its terminal primarily handles ***conventional general cargo traffic*** and is thus ***a clean case*** for the master thesis analysis of this kind of traffic and can be representative for this cargo traffic in all of Rogaland. The data used for showing (visualising) and calculating the variations are collected from SafeSeaNet Norway (SSN-N), which was described in chapter 1.4. The SSN-N data comprises of estimates are given by the ships, ship agent or others doing this on behalf of the ship at different point of time before arrival or departure and the actual time of arrival / departure to / from berth is captured by AIS signals. Both are needed to calculate the total sum of variation hours, $\Delta h(\text{total}) = \sum(\Delta h=\text{ETA-ATA})$.

In the *Port of Sandnes* case there are collected data from five ship types "General Cargo Ship" (100 port calls), "Refrigerated Cargo Ship" (89 port calls), "Ro-ro Cargo Ship" (35 port calls), "Palletised Cargo Ship" (6 port calls), "Container Ship" (1 port call) from 22nd of June 2016 till 9th of October 2017 that are used in the following study and calculations. These ship types are the ones that are mostly doing "Discharging"-, "Loading"- or "Discharge/Loading"-

operations and thus have the most use of persons out of the voyages purposes done in the port. There were 18 port calls made by other ship types which was visiting in lower frequency (“Crane ships”, “Offshore Supply Ships”, “Offshore Support Vessels”, “Standby Safety Vessels”, “Buoy/Lighthouse Vessels” and “Training ships”) who were mobilizing or performing other cargo operations. Ship types of type “Crew boat”, “Passenger Ferry”, “Tug” and “Yacht” were intentionally left out from the study because of the nature of these ship types, which are not to transport gods but other auxiliary support or pure transport of passengers.

As described in chapter 4.6.4 there has been applied some filters on both valid ship types, maximum time lines and removal of extreme values. This has been done so because of findings in the course of data analysis, where changes, to find a best selection of relevant data for the visualisations and calculations. The interviews with the maritime experts referred to in previous text has also contributed to these filters.

Based on the estimates and the actuals, of the above selection, we can calculate total deviation to all the arrivals and also present the variations to arrival and departure messages along a timeline showing the “Time of report / Notification time”. The total hours of deviation can be done by summarizing all the individual deviation hour’s the ships are arriving or departing later or earlier than planned. Let’s first take a look on the scatter charts of the ship arrivals and departures and then move on to the final calculations of total variation hours and their potential cost.

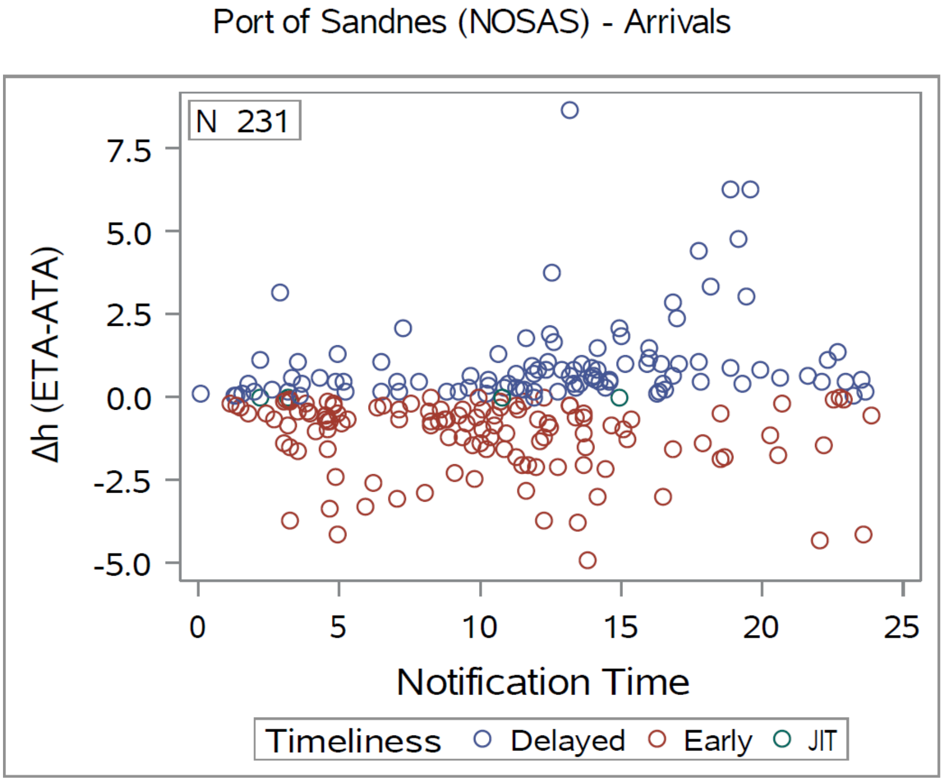


Figure 28 Arrivals NOSAS (ETA_0) 24 hour filter

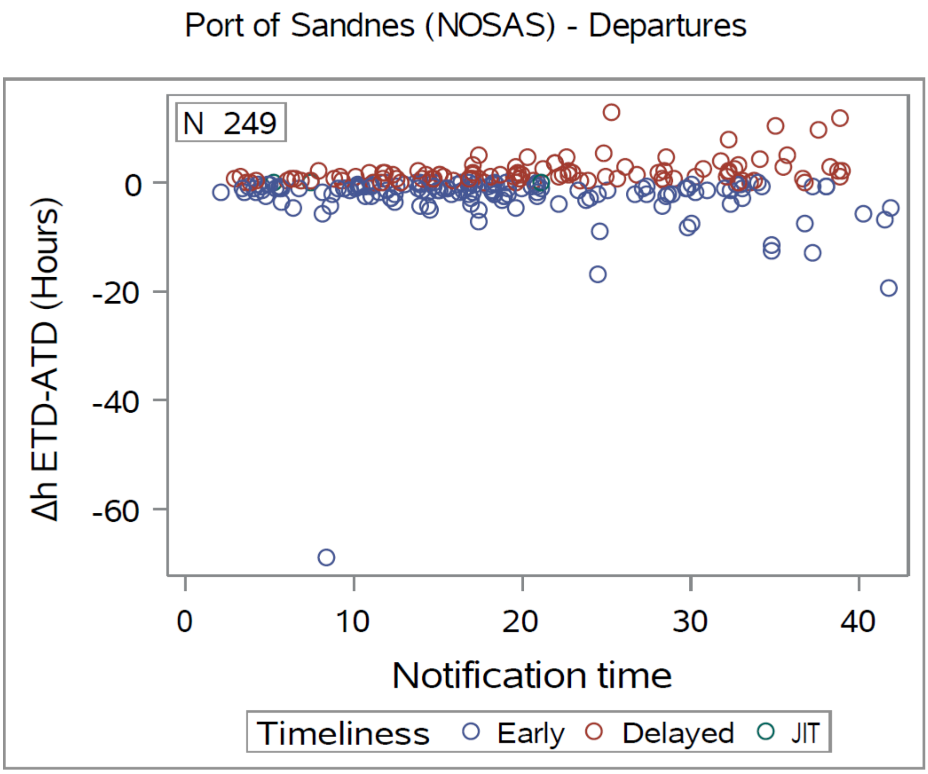


Figure 29 Departures NOSAS (ETD0) 42 hour filter

In the two figures above we see the "Notification time" along the x-axis. The deviation Δh is shown along the y-axis. Too early arrivals (Figure 28) and too early departures (Figure 29) are shown as negative (-) y-values. Too late departures or arrivals are shown as positive (+) y-values. The y-value deviations are showing as circles, which shows if there are differences in the message at the time of notification to the actual time of arrival (ATA) or departure (ATD). The actuals in each scatter plot is where the y value is zero (y=0).

By looking at the scatter plots we see that the deviations of the arrival messages estimates (ETA), by visual observation, seem to range from +9 hours (late arrivals) to -5 hours (early arrivals) in the 24 hours of observations. The spread of the departure messages (ETD) seem to be bigger, and if we exclude the one extreme value of around -70, we can observe that it seems to lay within a +/- 20-hour range for the 42-hour notification time interval. This shows us that the departures seem more difficult to handle or predict for the ships and *Sandnes Havneterminal AS*. Let's move on to calculate how much this deviation are in hours, and if we can calculate a potential cost for the terminal from these "wasted hours".

Below we see the total hours calculated from the "circles" in the two scatter plots in Figure 28 and Figure 29. The calculations for the total deviation hours of the arrivals and departures are calculated by using the difference between the ATA (Actual Time of Arrival) and the ETA (Estimated Time of Arrival) for the arrival calculations, and the difference between the ATD (Actual Time of Departure) and ETD (Estimated Time of Departure) for the departure calculations. Arrival calculations are based from the last 24 hours of ETA_0 arrivals messages and the departure calculations are made from the ETD_0 departure messages made in the last 42 hours' departure where the average berth stay of ships in Rogaland are added to get the departure estimates from as many of the arrival messages as possible. We then get the following result:

	Number of unique port calls	Early (total sum in hours)	Late (total sum in hours)	Total $\Delta h(total)$
Arrival[5]	231 (out of ca. 800)	143,85	108,05	251,9
Departure[6]	249 (out of ca. 800)	403,65	202,35	606
Sum	-	-	-	857,9

Table 9 Calculations deviation hours NOSAS (ETA0 / ETD0 registrations)

We see that we have around the same amount of observations on the arrival as on the departure side. This may indicate that using a 42 hour "Notification time"-timeline for the departures is correct. The observations are based on around the potential 873 vessels are reporting to NOSAS (Sandnes Havneterminal AS / *Port of Sandnes*) via SSN-N or other channels in a 16-month period; The figure is an estimate based on the 655 ships visiting in 2016 (Port of Sandnes, 2018a). As seen from the table the number of departure deviations hours, are in sum, more than double that of the sum of deviation hours of arrivals. This gives a good indication that departures are more unpredictable and uncertain than arrivals, as we also could see from the visual observations (visual: more uncertain method).

4.6.5.1 Operator waiting times (H1.1.1.1.1)

Looking from a terminal operator's perspective early or delayed ship arrivals or departures has to be managed on a daily if not hourly basis. It is the goal of the operation manager to mitigate variance to the lowest level possible in port or terminal operations and strive for Just-in-time (JIT) operations. To change the execution of one task or a series of operational sequences may be impossible to handle due to variance and a "Bull-whip" effect may occur in the whole value chain in both down- and upstream direction. If there are no means to mitigate these variances, this variance might cause this to be "total waste of time". If the next ship in line has to agree to use earlier or later time slots, this in turn may influence other ships and terminals as well as third parties that in turn need to shift their operational plans. The ability to get quantitative data of early or late ship arrivals or ship departures in real time, as early as possible, will have a big impact on the port or terminals ability mitigate operational variance. If handled in a correct manner this situational awareness can help them, their customers and other stakeholders in optimizing their day to day business. Having the sum of total deviation,

[5] Based on ETA_0 unique message estimates given in SSN -N notifications 24h or less before arrival
[6] Based on ETD_0 unique message estimates given in SSN-N notifications 42h or less before arrival

we can do an estimate of the cost these deviations may have. In the following calculations, the mobilization time of early arrivals are also used as a cost for the delayed hours of work, even if the delayed hours may represent income in form of “more sales”. There may a short term win, but due to the uncertainties the sequential costs may be great if other ships are waiting and the use of overtime results in resting times, which influences the same or other berth operations. This master thus deems the sequential costs for the port and the rest of the supply- and value chain to be considerable and is assumed to be the same cost per hour for late departing ships and for earlier departing ships as well as for the later or earlier hours of ships arriving. There is therefore a need in future studies to go more into the depth of sequential costs as well as the supply- and value chain costs. Let’s see how the man-hour cost is calculated in the “financial reflections” below.

4.6.5.2 Sandnes Havneterminal AS (NOSAS) - Financial Reflections (H1.1.1.2 / H2.1.1.1.1)

After interviewing some of the employees at the terminal about how many employees are needed doing cargo operations it got clear that this depend on the ship and cargo. According to the interview objects the men used for serving cargo operation may vary from 2 till 8 operators. The terminals best guess was that they in average would have 5 employees on a typical ship with not too difficult cargo (Steel pipes being the more complicated of the operations).

In this case we only look at the deviance/variance hours ($\Delta h_{arrival}$ = ETA-ATA) / ($\Delta h_{departure}$ = ETD-ATD) and not the operational hours of the whole birth visits (ATA to ATD). What we want to do is to isolate and calculate a best estimate of what the operational variance costs the *Port of Sandnes*. Knowing that the total deviance occurred in a 16-month period is around 857.9 hours = Δh(total), we need to calculate the man hours and multiply them with the salaries and deviation. If the average ship needs 5 employees to operate cranes, fork lifts, hook-up and other tasks (H1.3.1), this mean that there are about 4289.5 man-hours cost in this period caused by deviance. An average of approximately 268 man-hours each month.

If we know the salaries of the employees (direct cost) we can calculate how much this can cost the terminal and *Port of Sandnes*.

A employee in Norway can earn between ca. 77.000 USD[7] and 130.000 USD (Between 600.000 NOK and 1.000.000 NOK) in yearly salary (1725 man hours per year). If we do not include the social costs this is between ca 45 USD and 75 USD per hour per employee. This simplified calculation does only take in account the direct cost of wages, not social costs or the other direct or indirect operating cost to the *Port of Sandnes*.

The when using an average of 268 man-hours per month, the cost deviation caused by ships arriving late or too early lies somewhere between 144.000 USD and 242.000 USD for a 12 months' period.

4.6.6 Rogaland county – Arrival times and cost

The following section shows the findings when analysing the arrival and departure variance of voyages made in Rogaland for the ship types *"General Cargo Ship"*, *"Refrigerated Cargo Ship"*, *"Ro-ro Cargo Ship"*, *"Palletised Cargo Ship"*, *"Container Ship"* with valid data from 22nd of June 2016 till 9th of October 2017. The scatter plots and calculations used are following the same method as for the case "Sandnes Havneterminal AS".

The calculations made for Rogaland is also presented in the article ***"Balancing just-in-time operations – Coordinating value creation" (Lind et al., 2018)***, where the author of this paper (Terje Rygh) is one of the co-authors. The article was released on Sunday the 18th of march 2018 on http://fathom.world which is an *"is an online news and analysis service dedicated to providing insight and knowledge on the transformation of shipping."* The article was also published on the professional network platform LinkedIn where it was viewed a total of 2472 times in four days. Article can be found in its full length in Appendix 7 – Balancing just-in-time operations – Coordinating value creation.

[7] NOK/UDS = 7.72, pr. 20th of March 2018

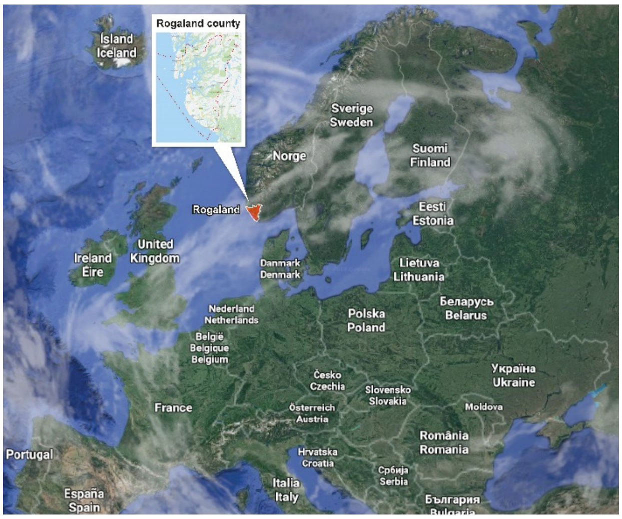


Figure 30 Map of Rogaland County, Norway(Rygh and Google maps, 2018b)

Rogaland county is the third biggest maritime economic region in Norway only surpassed by the Oslo-fjord and Bergen region. It is situated on the southwest coast of Norway. Some of the major ports and terminals/terminal operators located in Rogaland are the Port of Stavanger, Port of Karmsund, Port of Egersund, *Port of Sandnes*, Kårstø (Statoil), Westport, NorSea (Dusavik/Tananger), ASCO and Kuehne & Nagel. According to the data collected from the national single window (SafeSeaNet Norway) there are registered about 19.000 unique ship arrival voyage registrations per year in the whole of Rogaland (2016: 19.451).

The two following scatter plots have already been shown in Figure 20 and Figure 21, they represent the starting position of the Rogaland analysis before of all the filters are applied that using the method described in chapter 4.6.4.

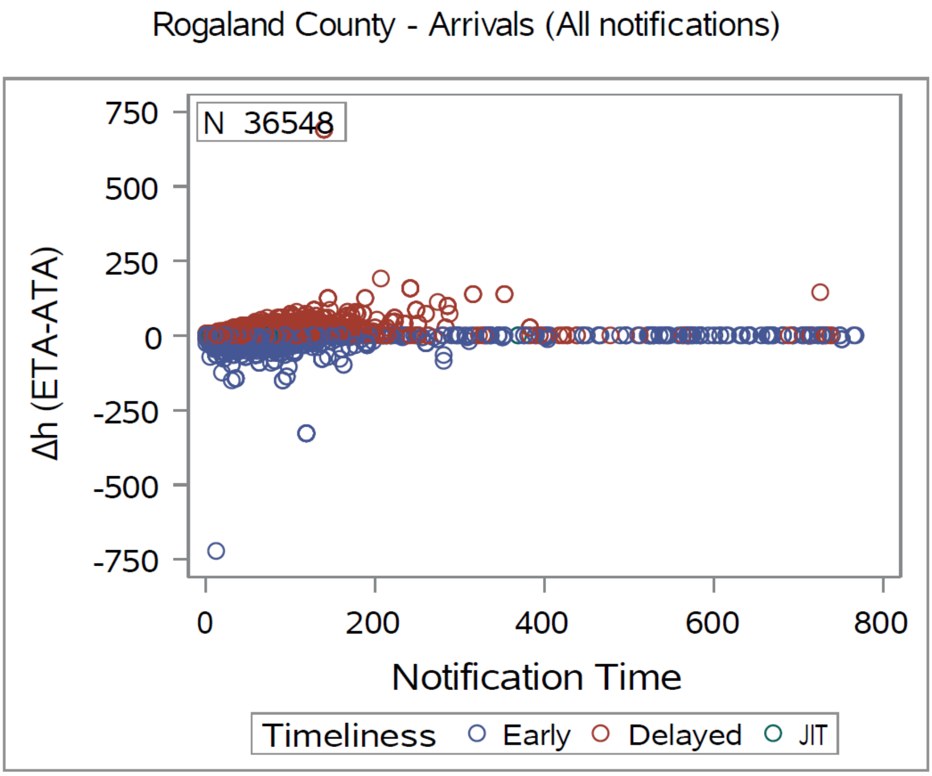


Figure 31 All arrival notifications (SSN-N)

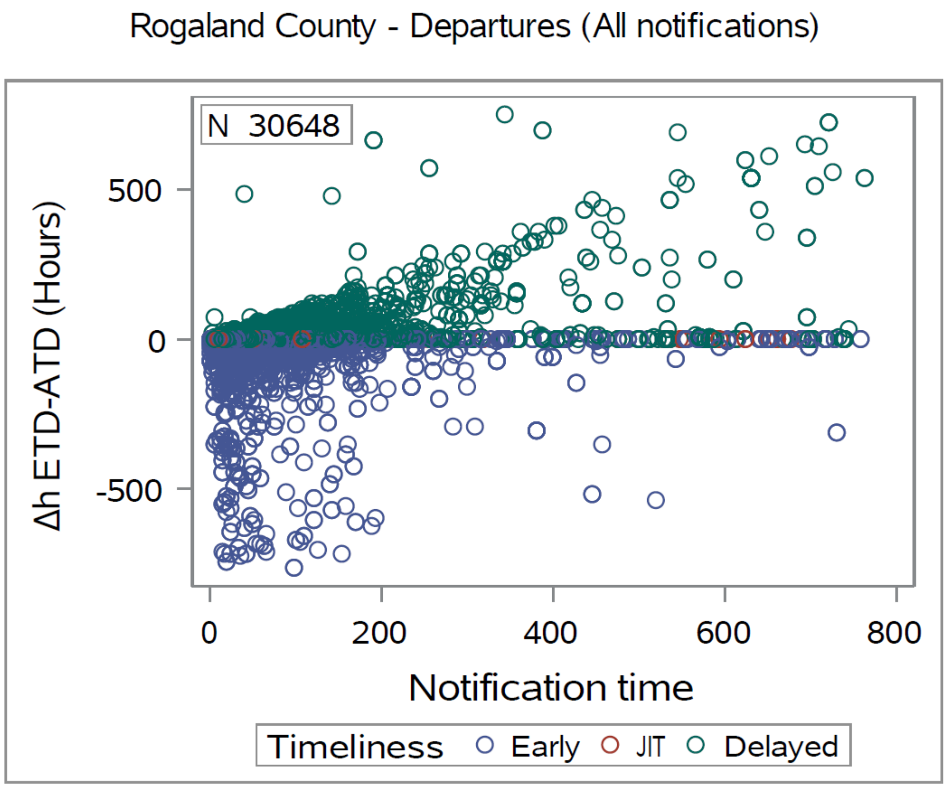


Figure 32 All departure notifications (SSN-N)

In the two figures above we see the "Notification time" along the x-axis. The deviation Δh is shown along the y-axis. Too early arrivals (Figure 35) and too early departures (Figure 36) are shown as negative (-) y-values. Too late departures or arrivals are shown as positive (+) y-values. The y-value deviations are showing as circles, which shows if there are differences in the message at the time of notification to the actual time of arrival (ATA) or departure (ATD). The actuals in each scatter plot is where the y value is zero (y=0).

By adjusting the length of the x-axis, to the 24h and 42h filter, still keeping the many voyage update registrations we get the following two scatter charts:

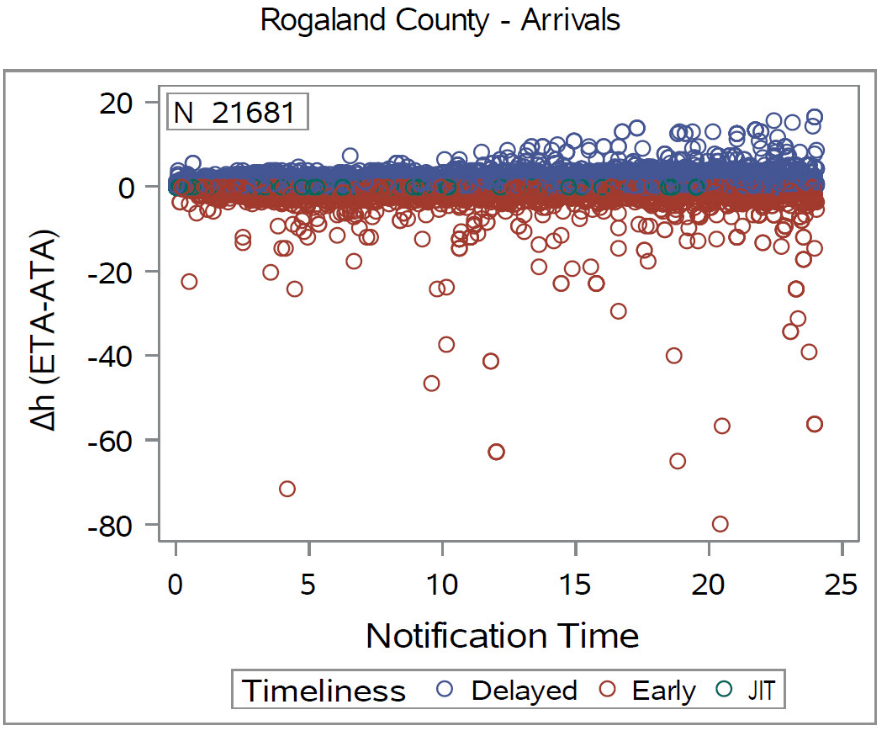


Figure 33 All arrival notifications (SSN-N) 24h filter

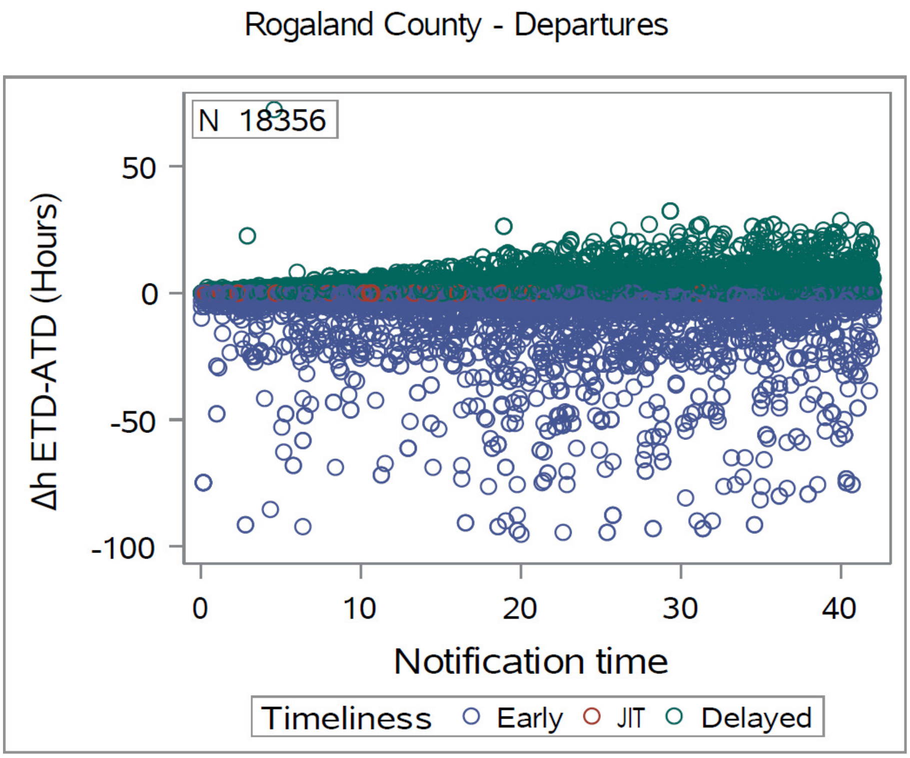


Figure 34 All departure notifications (SSN-N) 42h filter

We can see that reducing the number of hours that we collect samples from that both figures have the same shape with a difference that the departure figure seems to have a bigger spread.

Within the last 24 hours of the Actual Time of Arrival (ATA) there are a total of 21.681 registrations and update messages to the ships Estimated Time of Arrival (ETA) as seen in Figure 33 above. In the last 42 hours before the Actual Time of Departure (ATD), there are 18356 estimated time of departure registrations and updates as seen in Figure 34 above.

When filtering as described in the method described in chapter 4.6.4 *Visualising Arrival times and Cost*, we get the following scatter charts:

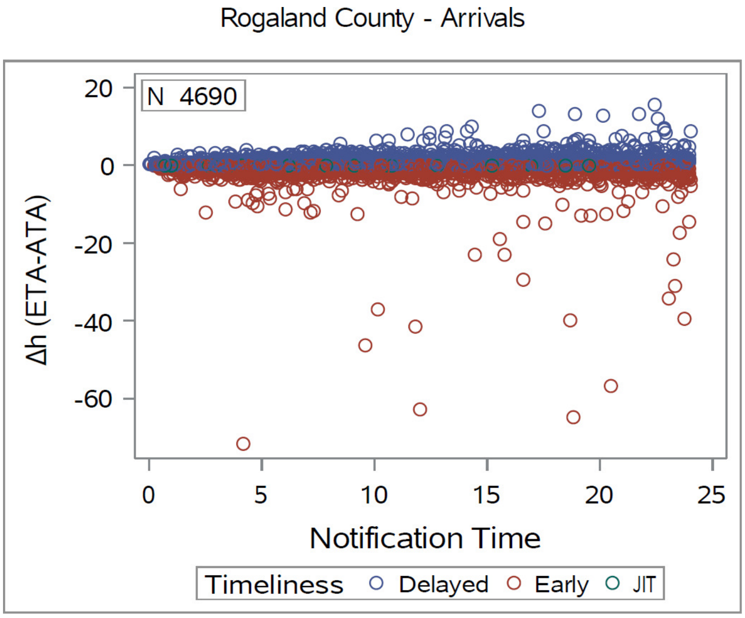


Figure 35 Arrivals Rogaland (ETA0) 24 hour filter

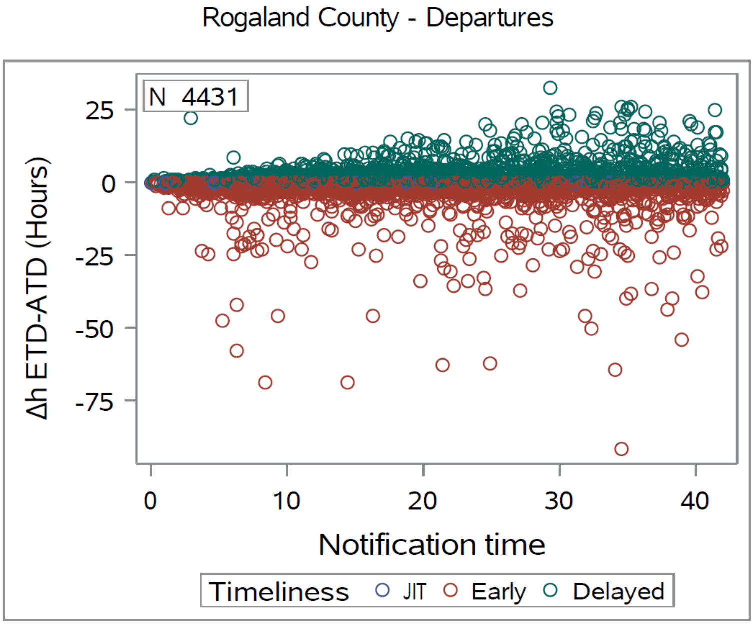


Figure 36 Departures Rogaland (ETD0) 42 hour filter

By looking at the scatter plots we see that the deviations of the arrival messages estimates (ETA), seem to range from +20 hours (late arrivals) to -75 hours (early arrivals) in the 24 hours "window" of observations. The spread of the departure messages (ETD) seem to be slightly higher, as it seems to lay within around +30 hours (early departures) to around -90 hours in the 42-hour range of observations. This shows us that the departures seem more difficult to handle or predict for ships or terminals in Rogaland, but also show that the terminal in the *Port of Sandnes*, *Sandnes Havneterminal AS* scores better than the same ships types doing cargo operations elsewhere in Rogaland. Let's move on to calculate how much this deviation are in hours, and if we can calculate a potential cost for the ports and terminals in Rogaland.

4.6.6.1 Rogaland - Financial Reflections (H1.1.1.2 / H2.1.1.1.1)

The sample looked at in the case contains data from 16th of June 2016 till 24th of October 2017 (16 months). We look as stated earlier at four ship types "General Cargo Ship" (3764 port calls), "Ro-ro Cargo Ship" (441 port calls), "Refrigerated Cargo Ship" (284 port calls), "Palletised Cargo Ship" (125 port calls) and "Container ship" (77). Usually these ship types do conventional cargo operations as stated earlier and the end product is therefore the deviations of the specific ship types who operate in the County of Rogaland.

By calculating the difference between the ATA (Actual Time of Arrival) and the ETA (Estimated Time of Arrival) as well as ATD (Actual Time of Departure) and ETD (Estimated Time of Departure) for the notifications given 24 hours or less for arrivals or departures, we get the following:

	Number of unique port calls	Early (total sum in hours)	Late (total sum i hours)	Total $\Delta h_{(total)}$
Arrival[8]	4690 (out of 16711 valid[9] unique arrival notifications of all ship types in Rogaland)	3.311,2	2.225,93	5.337,13

[8] Based on ETA_0 unique message estimates given in SSN -N arrival 1st arrival notifications 24h or less before arrival

[9], [11]Valid data = Contains both estimates (ETA_0/ETD_0) and actuals (ATA_0/ATD_0) of arrival and departure

Departure[10]	4431 (out of 13301 valid[11] unique departure notifications of all ship types in Rogaland)	7.703,5	4.977,98	12.681,6
Sum (in hours)	-	-	-	18.218,6

Table 10 Calculations deviation hours Rogaland county (ETA_0 / ETD_0 registrations)

Looking at the sums in the “Early” and “Late” we see that the departures have more than the double of deviation hours than the arrivals.

Using the average 5 employees on a typical ship and salaries, found in the case of “Sandnes Havneterminal AS”, the hours of deviation a 16-month period is around 18218,6 person hours (Δh_{total}).

These terminals working hours may be a “total waste of time” if a ship is late and the terminal employees have nothing else to do. This gives a monthly potential cost and the loss of these man hours can be calculated when person hours are multiplied by the salaries. In the other case, when a ship comes early mobilizing the employees may have a mobilization cost to the terminal, but also may give a problem with resting times and *sequential effects* of operations may have a cost further down the line when drawing away resources from other arrivals, or having “waste hours” because there are no work between the early arrival and the next ship which does not arrive earlier but arrives as scheduled due to them saving fuel costs or cannot get their “engine” to run significantly faster.

The interviewed employees in *Sandnes Havneterminal AS*, said that the best estimate needs of employees on an average ship is to have 5-6 employees to operate cranes, fork lifts, hook-up and other cargo handling tasks (H1.3.1). In this case we assume that this also applies for the other terminals in Rogaland and have chosen to use the lowest number of employees, taking a conservative stand, using an average of 5 employees per berth visit (SSN-N voyage). This mean that there are about 114.101,5 person-hours cost in this period caused by deviance, when using the same average on the cargo ships going to all of the terminals and ports in Rogaland county. This amounts to an average of approximately 5693 person-hours each month (approximate 16 month containing valid of data).

[10] Based on $\underline{ETD_0}$ unique message estimates given in SSN-N’s 1st arrival notifications 24h or less before arrival

When using the yearly salary rates used in the previous case of “Sandnes Havneterminal AS”, and the same method and reasoning, we can calculate some of the direct cost by inductive reasoning for all terminals visited by similar ship types (which primarily handles ***conventional general cargo traffic)***. This means that the hourly rate is between about 45 USD and 75 USD per hour per employee. This simplified calculation only takes in account the direct cost of wages, not social costs or the other direct or indirect operating cost.

The when using an average of 5693 person-hours per month, the cost deviation caused by ships arriving late or early lies somewhere between 3.074.000 and 5.124.000 USD for a 12-month period due to that the employees had to wait or show up early for serving the ship and not having any capabilities to re-plan or do work in other sequence. These are tremendous sums and even if there are many factors of uncertainties in this study (Like how well the terminals can manage to change processes and mitigate the sequences of waiting time or mobilization time and when is the critical time where the ports and terminals cannot handle variation).

Because goods may have many stops before their destination and the variance in one part of the value and supply chain this deviation and unevenness at the terminals may have big impacts on other parts of the chain. What the loss of time world-wide and the implicated cost are for value chain actor like Amazon and Alibaba, which are both receiving goods and sending goods by ships, are mere speculations. But the quality of ship arrivals (predictability and punctuality) should be a high priority for them. The initial variance at the terminals may grow bigger in the downstream supply and value chain (H1.3.1.1/H1.3.2.1) and for these big actors these variations are definitely something they have to look into and should also be investigated in future studies by the ports and terminals, as well as the goods owners and customers on the top of the logistical value chain.

4.6.7 The North Jæren region – Arrival times and cost

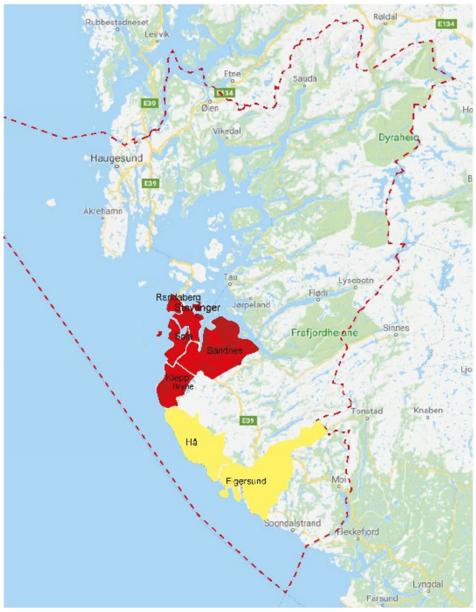


Figure 37 North Jæren region (Rygh and Google maps, 2018a)

The North Jæren region comprises of the four municipalities "Stavanger, Sola, Randaberg and Sola" (Wikipedia, 2018a) in Rogaland county. The author has allowed himself to include the Unlocodes in the municipalities of Rennesøy and Egersund as well into the data observations to have the some more data as the valid observations (having both estimates and actuals) were not as big as hoped for in the original 2014-2017 data set given from the Norwegian Costal Administration (NCA).

The original arrival data set comprises of 16575 valid data observations where 8382 observations are unique (ETA_0 values) which is used in the method described in chapter 4.6.4. The original departure data set comprises of 13.544 valid data observations where 6427 observations are unique (ETA_0 values).

When using the same method as for the terminal "Sandnes Havneterminal AS" we get the following two scatter plots showing all the valid data (having both estimates and actuals) recorded for all unlocodes in the above mentioned municipalities.

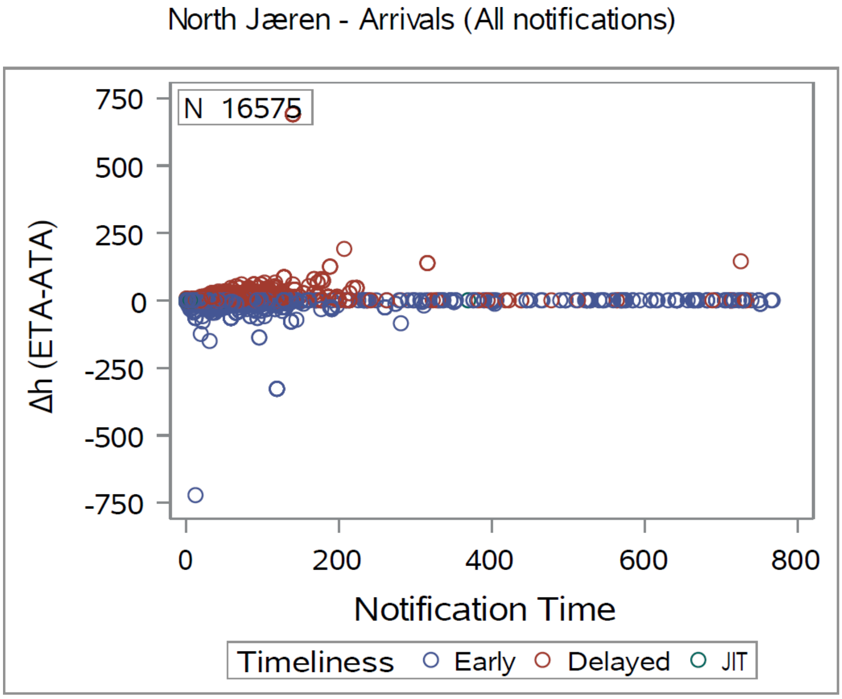


Figure 38 North Jæren - Arrival (All ETA notifications)

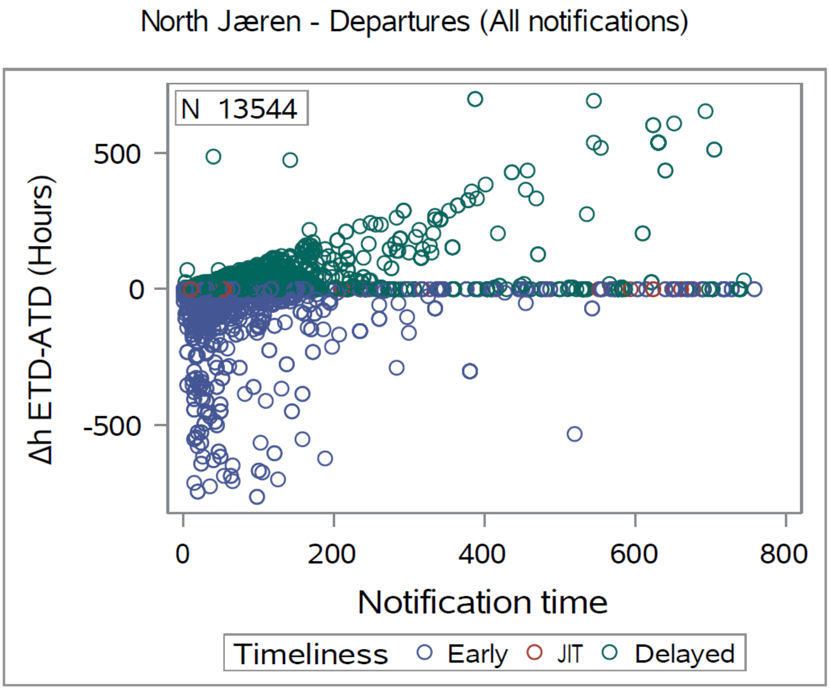


Figure 39 North Jæren - Departure (All ETD notifications)

In the two figures we see that the spread and deviation of the ships in North Jæren is very similar to the pattern seen in Rogaland. The departures are showing the same big spread when compared to the arrival data. Below we see the data set when using the ETA_0 and ETD_0 data used as baseline for the total deviation hour calculations.

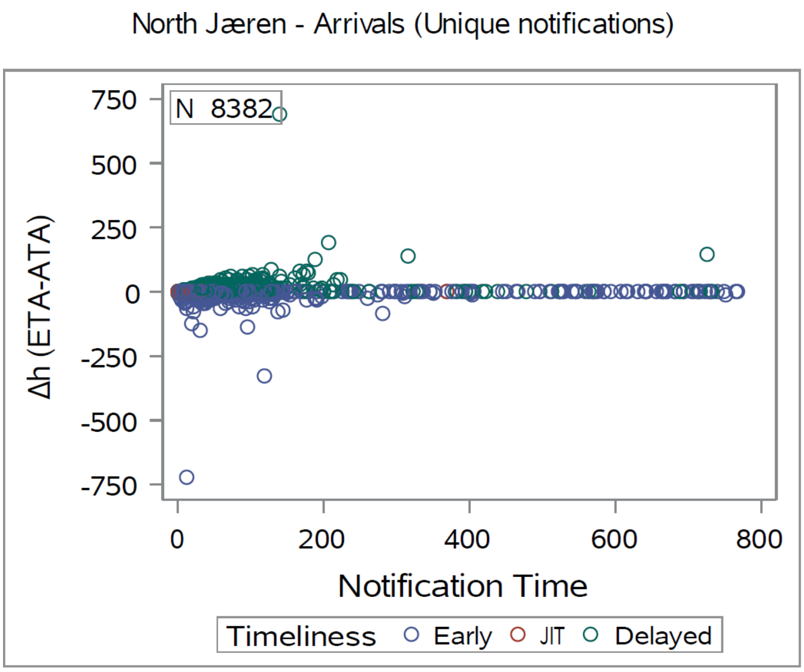


Figure 40 North Jæren - Arrival (ETA_0)

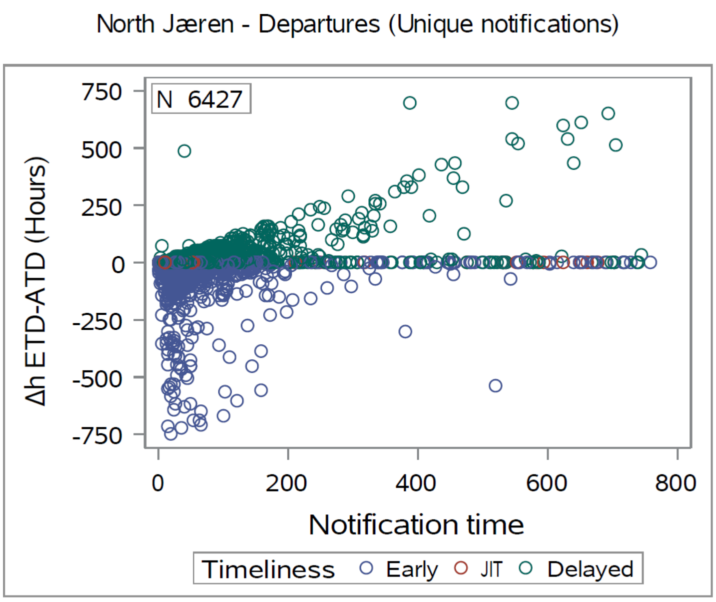


Figure 41 North Jæren - Departure (ETD0)

The first registrations are fewer in number bus has not significantly changed in shape or range of the deviations. The departure voyages are still having the biggest spread.

When using the notification filters of 24 hours for the arrival estimates and 42 hours of the departure and filtering away the 96 hour extreme values of the estimates, the scatter diagrams looks like this:

North Jæren Region - Arrivals

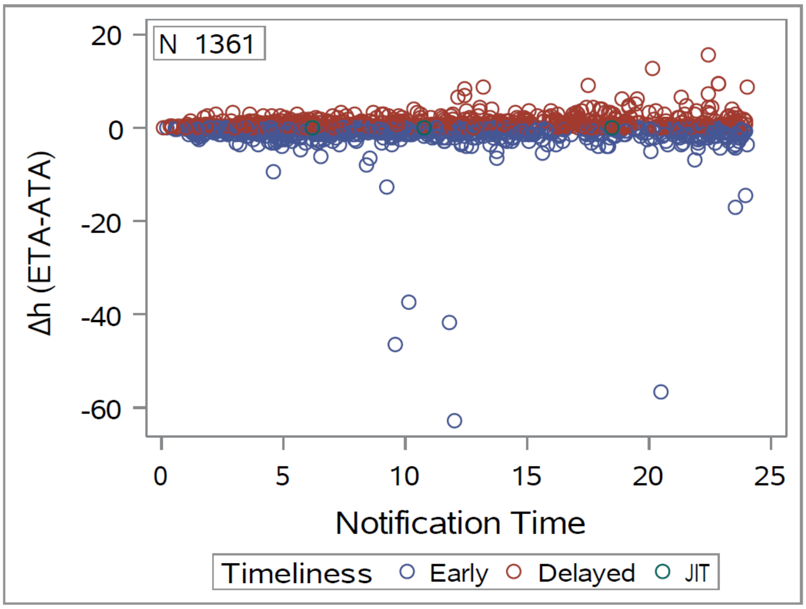


Figure 42 North Jæren - 24 hours prior to Arrival (ETA_0)

North Jæren Region - Departures

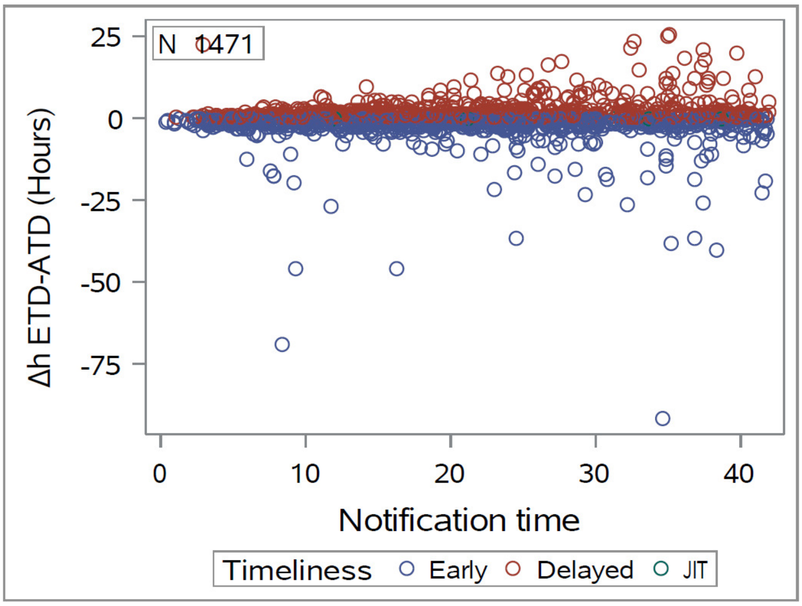


Figure 43 North Jæren - 42 hours prior to Departure (ETD_0)

As seen the samples of both arrival and departures seem to have the same shape but different spread.

4.6.7.1 North Jæren - Financial Reflections (H1.1.1.2 / H2.1.1.1.1)

The sample looked at in the case contains data from 16th of June 2016 till 24th of October 2017 (16 months). We look as stated earlier at four ship types "General Cargo Ship" (3764 port calls), “Ro-ro Cargo Ship” (441 port calls), “Refrigerated Cargo Ship” (284 port calls), “Palletised Cargo Ship” (125 port calls) and “Container ship” (77). Usually these ship types do conventional cargo operations as stated earlier and the end product is therefore the deviations of the specific ship types who operate in the North Jæren region.

	Number of unique port calls	Early (total sum in hours)	Late (total sum in hours)	Total (Δh_{total})
Arrival[12]	1361 (out of 16711 valid[13] unique arrival notifications of all ship types in Rogaland)	1.010,1	7.09,68	1.719,78
Departure[14]	1471 (out of 13301 valid[15] unique departure notifications of all ship types in Rogaland)	2.291,92	1.525,3	3.817,22
Sum (in hours)	-	-	-	5.537,00

Table 11 Calculations deviation hours North Jæren (ETA_0 / ETD_0 registrations)

As we see the total estimated man hours are 5.537 hours in a 16-month period. When using 5 men per berth visit this sums up to around 37.685 hours. Divided by 16 months this give around 2355 man hours of deviations per month. When calculating the costs using the previous rate of 45 USD and 75 USD per hour per employee, we get the potential cost due to the variation and deviations of ship visits to be in the range of 1.245.000 USD to 2.077.000 USD for all 16 months. The yearly estimate by to ship arrival deviations may be in the range of between 934.000 USD and 1.553.000 USD per year due to the ship deviation times. This sum up to 30,49% of the total estimated cost for whole of Rogaland when looking at the conventional cargo ships visiting terminals or ports doing similar operations as the *Sandnes Havneterminal AS* in the *Port of Sandnes* and using above mentioned steps. The suggested method of having a

[12] Based on <u>ETA_0</u> unique message estimates given in SSN -N <u>arrival</u> 1st <u>arrival</u> notifications 24h or less before arrival
[13], [11]Valid data = Contains both estimates (ETA_0/ETD_0) and actuals (ATA_0/ATD_0) of arrival and departure
[14] Based on <u>ETD_0</u> unique message estimates given in SSN-N’s 1st arrival notifications 24h or less before arrival

"Information Sharing HUB (Ship – Port – Hinterland)" should have some positive effects, it may be difficult to prove without having the possibility to do all the steps in the whole Kaizen circle.

4.7 The second hypothesis (H2)

The second hypothesis (H2) postulates that *"Changes can contribute to new cargo transportation in North Jæren"*. The new method proposed by the author is the "winner" of the listing made in Figure 19 The weighted alternatives on page 68 above, which is to implement a *"Information sharing HUB (Ship - Port - Hinterland)"* at a national level by the Norwegian Costal Administration (NCA) or a private actor. This is the only "new method" discussed in its full length as the complexities to try to refute each of the "new solutions" would be impossible to do in a master thesis alone. The main methods and tools which should be used in the "new method" of making such a "maritime" HUB are those of TQM and Lean, and by doing never-ending continuous loop of Kaizen or PDCA/PDSA. The goal is in the two mentioned methodologies to reduce waste (H1.1.1.1.1/H1.1.1.2) and enhance quality for the customers (H2.1.1.1.1). The two loops 1 and 2 in

Figure 14 "Going from hypothesis to high level *observations"* on page 46, are both continuous loops. The first loop (1) is usually needed by the management which has to invest in new infrastructure, IT-tools and training (H2.1.1.2) and have commitment to the processes done in both circle 1 and 2. The empowerment of the employees are also important, commitment cannot just come from the management and TQM explicit tries to show how this can be done through the "flow" of activities shown in Figure 6 on page 28. Without the full attention by the whole organisation and the whole supply- and value chain there may not be a heightened quality for the paying customer.

Constraints

We have already discussed that it might be difficult to prove that "new methods" (H2.1/H2.1.1) listed in chapter 4.6.1 and 4.6.2 will have an effect without being able to run a full continuous circle of Kaizen as seen in Figure 10 on page 35. This makes it impossible to verify without doubt that this has a positive effect in reducing waste and increasing the quality. Even if there were the opportunity to run a full circle there is still the possibility that "a good choice made, has a bad outcome and vice versa". Therefore, this needs full commitment over time and thus lies constraints on what can be achieved within this master thesis regarding if the hypothesis can be refuted or verified.

Proposed method of verifying or refuting the hypothesis

The "winner" of the new methods is as said the "Information sharing HUB (Ship - Port - Hinterland)". This means that sharing information is a big part of the method for lowering waste and increase quality of the terminal and port operations. It is also the main focus of the PortCDM concept and its Port Call Message Standard to contribute to Just-in-time (JIT) operations.

The figure below is just an illustration of how a control chart as proposed used in TQM may pick up "alarms" when upper control limits (UCL) or lower control limits (LCL) are breached. The goal of both TQM and Lean is to be as close to the Mean line (CL) as possible at all times.

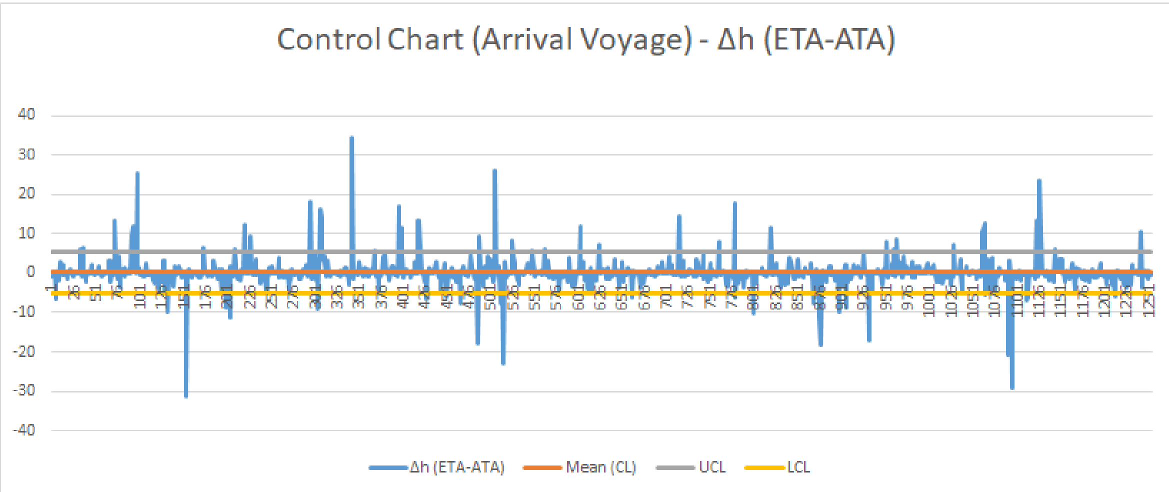


Figure 44 Control Chart example

The author therefore proposes to use historical data to test if "updating the arrival estimates" will help in such a chart. This is of course based on historical data, so the testing of a Kaizen circle is not an option as described above. The test will be to look at the arrivals (ETA) and Departures (ETD) in North Jæren and use 0.5 standard deviations from the mean (the North Jæren observations after the filters made in chapter 4.6.4 on page 76) to form the Upper Control Limit (UCL) and Lower Control Limit (LCL). In filtering away, the ETA_0 and ETD_0 (data from the first arrival registration) from the dataset only keeping the updates in the dataset, there might be a possibility to see if it has lowered the amount of estimates breaching the UCL or LCL.

"Doing estimate of arrival and estimate of departure" update experiments

In the SafeSeaNet Norway (SSN-N) data there are many updates and the author has chosen to check if doing updates improve the precision (quality) of their estimates (ETA and ETD) by visual observations of a control chart as shown in Figure 44 above. he blue coloured "graph" is the registrations and updates estimates of arrival (ETA) for both the first voyage registrations ETA_0 or their updates ETA_{0+n}. The grey line is the Upper Control Limit (UCL), the yellow line is the lower control limits (LCL) and the red line is the mean/average line (CL).

The prerequisite for using control charts

In order for us to do a good control chart exercise and be able to interpret the results we need to ensure that the distribution of the arrival and departure variances follow a normal curve.

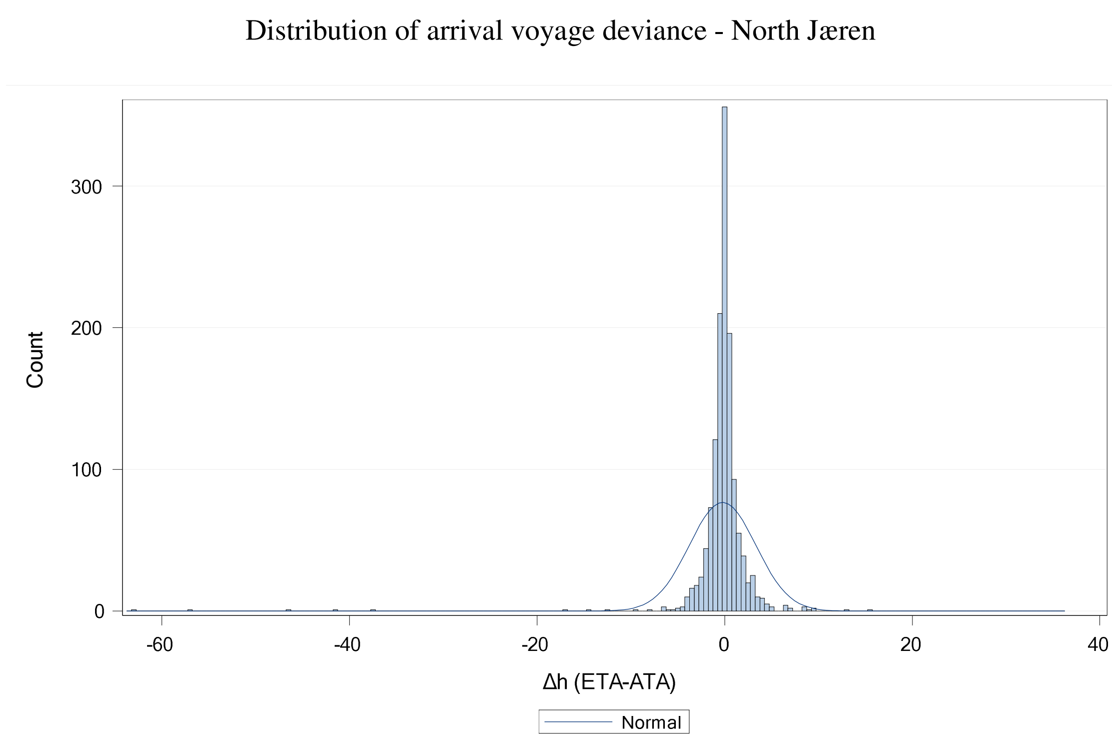


Figure 45 Histogram - Deviations of departure voyages North Jæren and their variation following a normal distribution

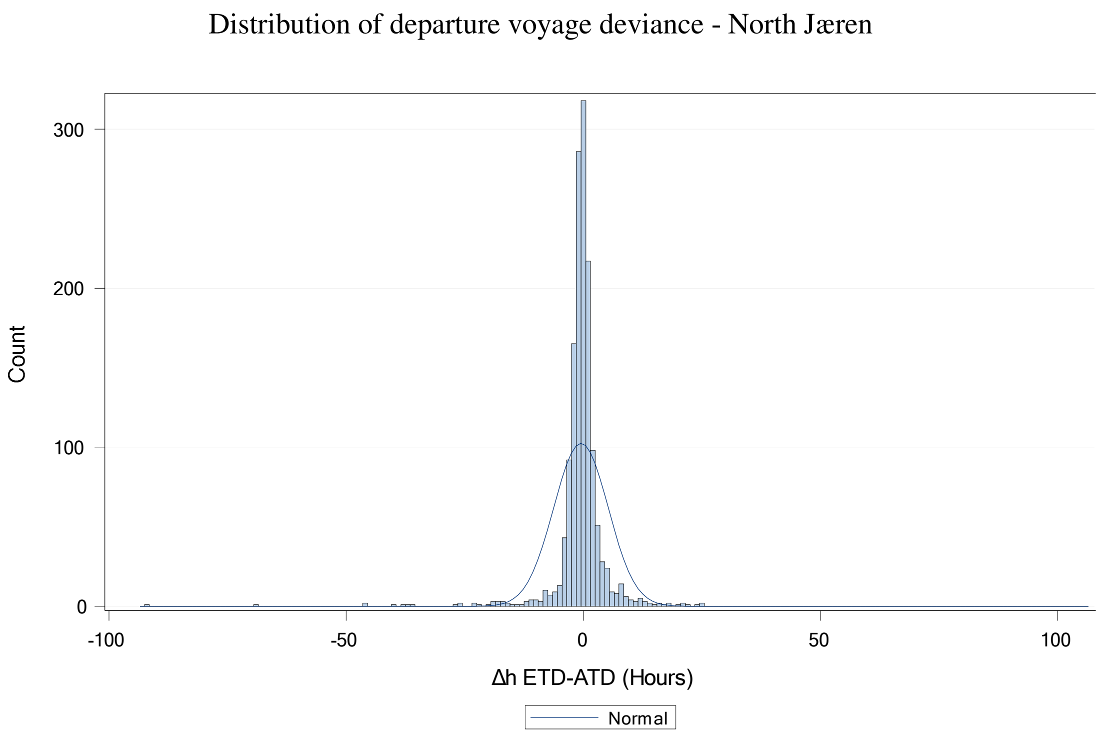


Figure 46 Histogram - Deviations of departure voyages North Jæren and their variation following a normal distribution

In *Figure 45* and *Figure 46* above we can see that for both arrivals and departures the deviation observations follows the normal distribution, it is then easier to interpret than if it would not have followed a N-curve. We therefore can say that we easier can interpret and use the TQM tool of Control Charts in our "experiment".

Arrival estimates North Jæren region and their updates

The first experiment looks at the variance and deviance from original estimates, by looking at the first estimated time of arrival ETA_0 and the updates done to the estimates (ETA_{0+n}) in SafeSeaNet Norway (SSN-N). The registrations when presented in a control chart, creates the following results in *Figure 47* and *Figure 48* below.

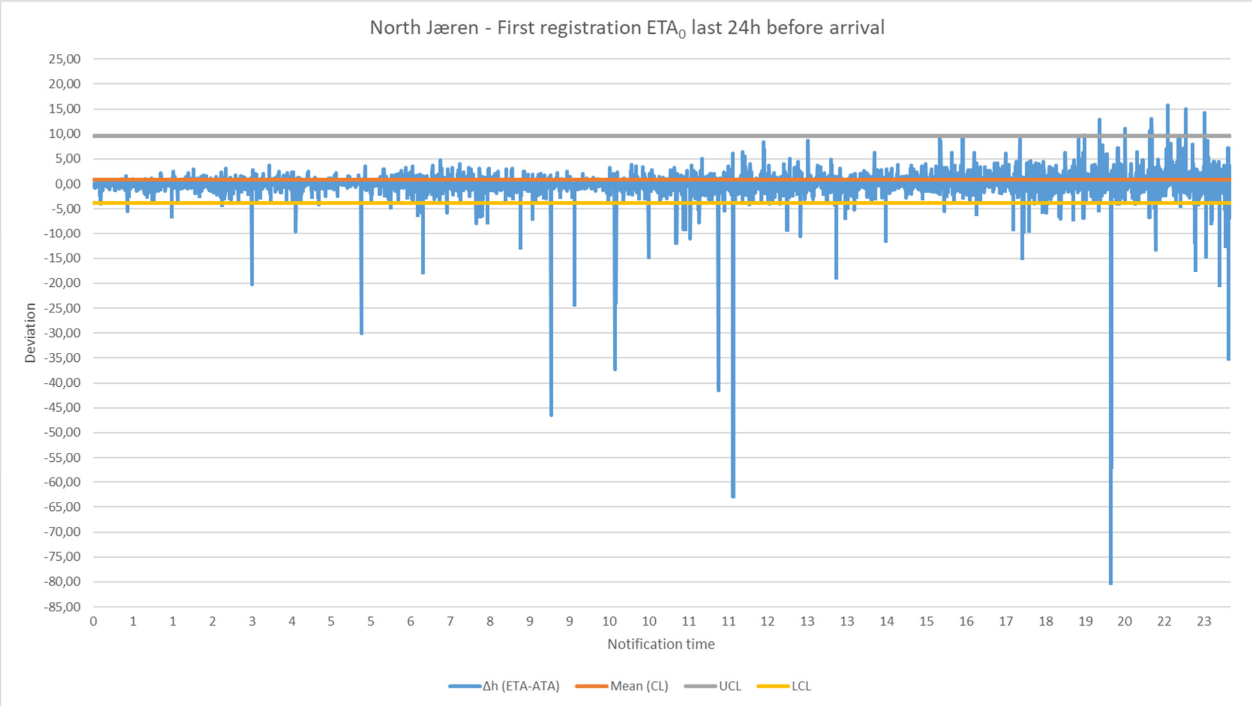


Figure 47 ETA₀ registrations made the last 24 before arrival (ATA) – 7310 registrations

In the chart we see the 7310 observations of the first registration of the estimated time (ETA_0 registrations) of arrival that ship have done in SSN-N. What we can observe is that the red line is slightly above the "imaginary line" where y=0. This means that the average registration is that of a ship that slightly arrives too late according to schedule. The blue lines on the other hand shown the deviation of each individual arrival message. Where the bars are long they might breach the control limits set to be 0.5 the length of the standard deviation. This means that 38,3% of all registrations should fall under the UCL and LCL lines, if the distribution of deviations follows a normal curve as we tested for above.

The UCL and LCL lines are breached several times and the "length" ("blue bars") of the arrival deviations that arrives earlier than expected are quite clear to see as they go all the way down to -60 and -80 in the extreme cases.

When we look at the *Figure 48 ETA0+n updates made the last 24 before arrival (ATA) – 3952 updates* below we see the updates have made an impact.

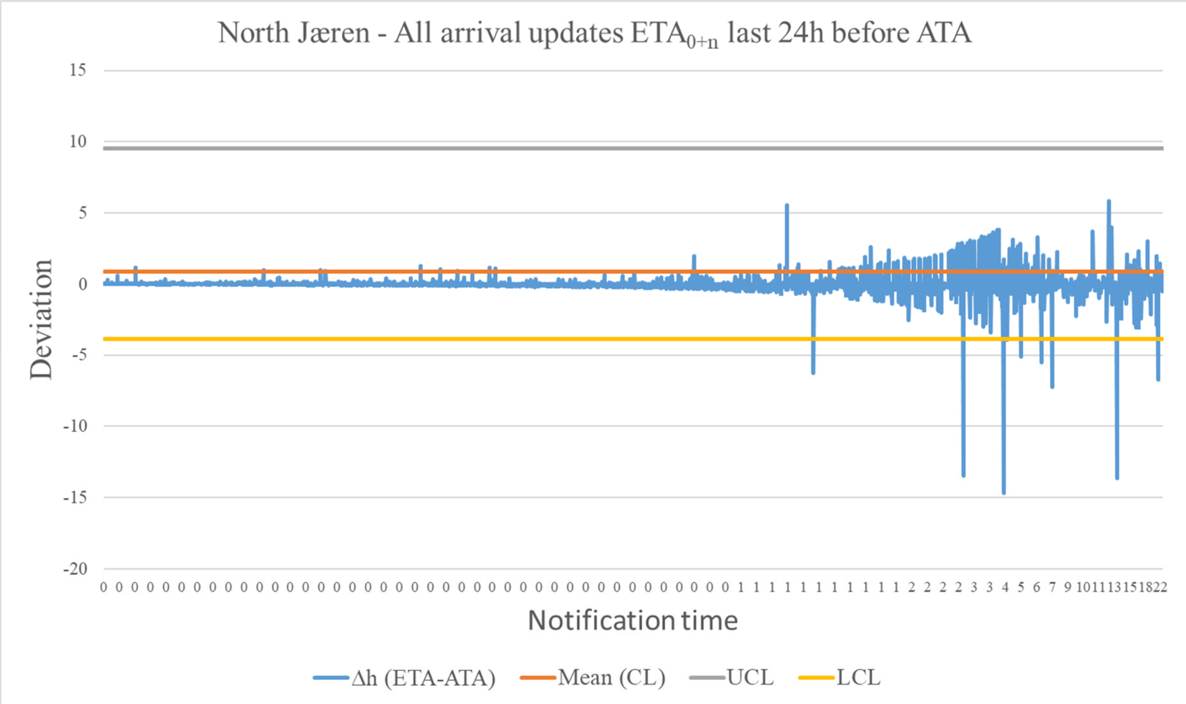


Figure 48 ETA$_{0+n}$ updates made the last 24 before arrival (ATA) – 3952 updates

In the chart we see the 3952 updates done ETA$_0$ registrations of arriving ship to North Jæren in SSN-N. We still see the median, ULC and LCL lines in their previous position as we have not done anything to them. What has happened is that the deviations represented by the "blue line" graph do not breach the control limits that often and the deviations of the most extreme deviation values are less than ¼ of the previous readings. This seems to support the H2 thesis that methods increasing the update frequency of intentions can help in mitigating variance to arriving ships.

Let's move on to the departing ships and see if we can find similar findings.

Departure estimates North Jæren region and their updates

The second experiment looks at the departure variations, and if updating the estimates can reduce the variance. The control charts seen in figure *Figure 47* and *Figure 48* above seems to follow the muster that we saw for the arrival estimates and their updates above.

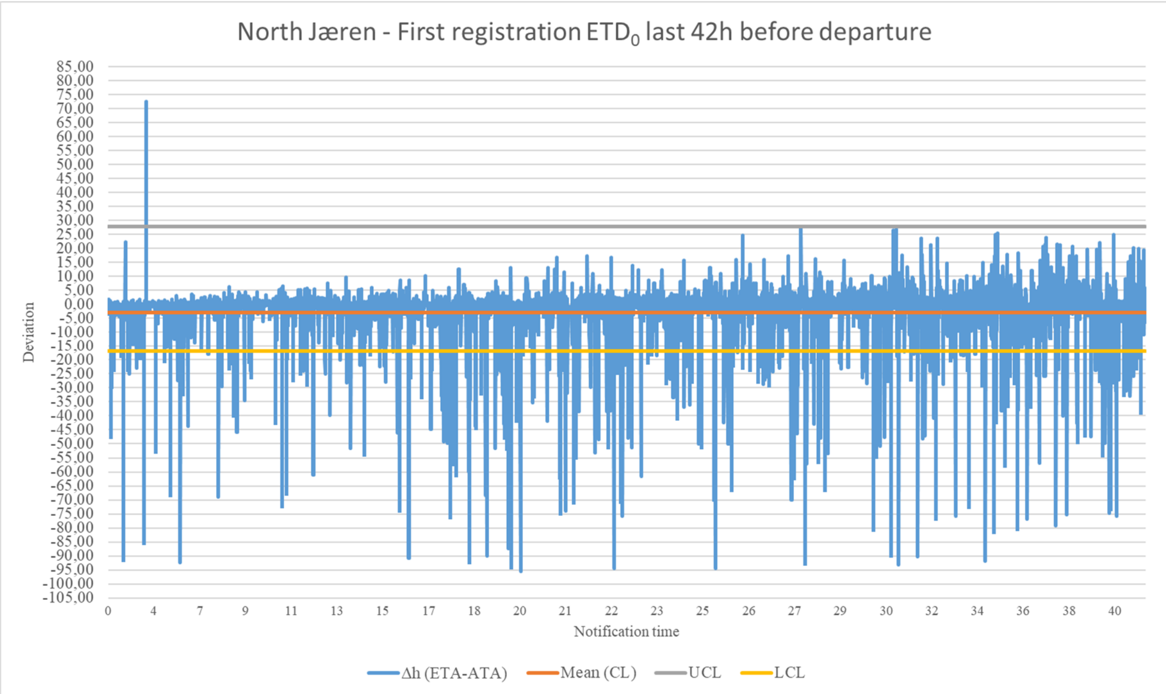


Figure 49 ETD₀ registrations made the last 42 before arrival (ATD) – 5780 registrations

In the first registrations of departure (ETD_0) we see that the early departing ships almost make a "curtain" pattern all along the Notification time (x-axis). This means that the ships of type "General Cargo Ship", "Ro-ro Cargo Ship", "Refrigerated Cargo Ship", "Palletised Cargo Ship" and "Container ship" quite often leave before schedule, even when reporting close to the actual departure time where x=0. This is a phenomenon which future studies might want to look into, but it could have a connection with the terminals ability to increase their "output" by using more labour and equipment which may be unproductive unless used. This is only a guess, but such findings could perhaps mean that the terminals have an overcapacity which lay unused in many cases. This is also if found a type of "waste" where idle machines or personnel heightens the cost for the terminals. The figure also shows that there are almost no breaches of the UCL line, which may imply that the ships have more incentives to leave earlier than late. This is also something that future studies might want to look into.

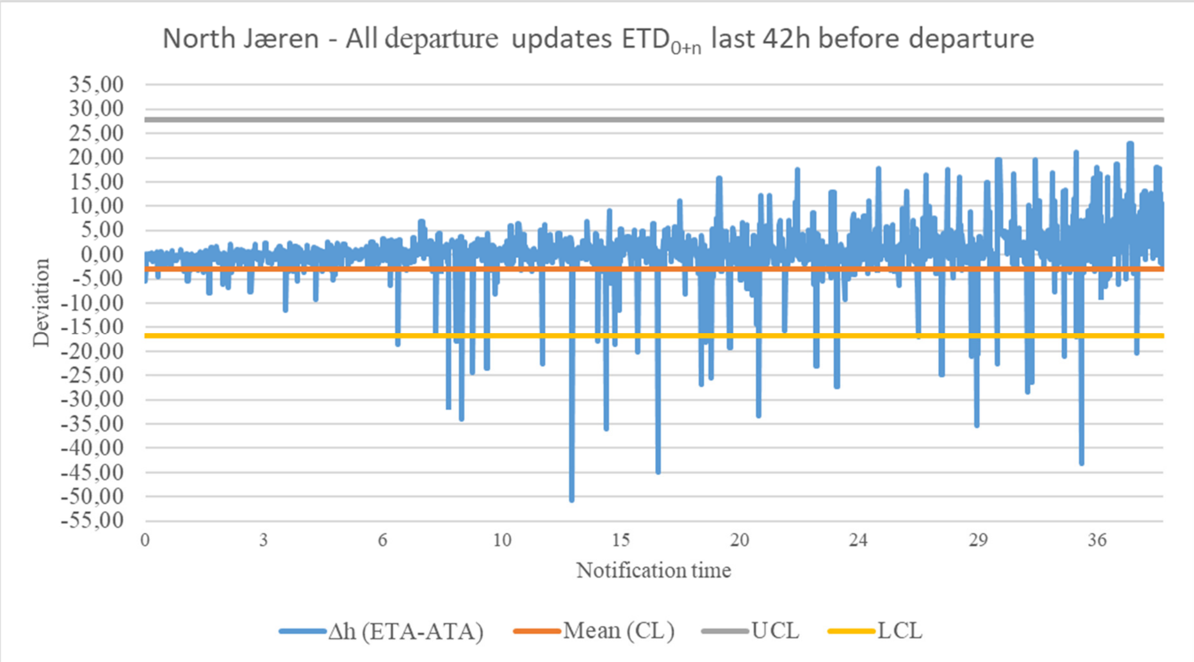


Figure 50 ETD0+n updates made the last 42 before arrival (ATD) – 2.182 updates

When looking at the updates and their impact on deviation in Figure 50 above, there still seems to be quite a number of early departures. But in the last 6 hours before departure there are no breaches of the LCL line. In addition, we can see that there are no breaches of the UCL. The last control shows us that updating the departure estimates looks to have a positive effect on the quality of the estimates.

5 Discussion / Verification

The master thesis has put forward two hypotheses which has been examined and tried verified:

- **H1: "New methods can make cargo transportation in North Jæren more profitable"**
- **H2: "Changes can contribute to new cargo transportation in North Jæren"**

Both hypotheses are the result of asking the initial question *"Can new changes help the maritime business to achieve better quality and reduce "waste" and thus enhance the customer value of their services?"*

The examination has been done by data collection, data manipulation and analysis, where the hypotheses have been exposed to several phases on their way to be verified or refuted. The nature and complexity has made it both needed and natural to do a discussion in the material leading up to this chapter. Thus much of the discussions presented below have already been discussed in earlier chapters, and the listings and explanations used in the continuation is therefore a summary of much of this.

By discussing each hypothesis, in the following chapters the end result should be the answer to the initial main question.

5.1 Reflections of used methodology

The author has tried to be as objective as possible in both data collection, interviews and analysis to achieve the best possible of the two postulated hypotheses and has throughout the master thesis tried to address uncertainties as the arise.

In using an inductive reasoning on the empirical data collected, the full independence from the authors choices and meanings cannot be avoided. As such the "full" objectivity and independence from the researchers' choices, is not achievable. The author has used both a qualitative and quantitative method in a mix. As well as used a case and done interviews where subjective reasoning plays a major part.

The author has limited experience in researching cases and doing interviews, this may be disfavour able factors, which in turn affects the result of the calculations and conclusions in the master thesis. Due to this there also may be faults in the calculations as a consequence, that may lead to another outcome than the results actually should have had. The case of *Sandnes Havneterminal AS* may have been the wrong case to choose, due to the few data samples. Or that, as the author acknowledges when discussing the findings of *Figure 25 Ship types arriving NOSAS* on page 83 the, in "hindsight", possibility that there might have been other outcomes to the data analysis if a filter combining both "ship types" and "voyage purposes" would have been applied as a method for filtering away the "general cargo ships" which do not do "conventional cargo operations" that was the intention to do. This may have affect the data, by adding more observations when they should not have been a part of the data set for the further analysis. In addition, the author has used a generalisation treating all deviance types (waiting time, mobilization time) as the same type of "waste" and loss for both departing ships as for the arriving ships. This means that the author has treated late or early arriving ships causing waiting time or mobilization time has the same cost as ships leaving early or later which may not cause a "negative effect" and cost for the ports and terminals. These two presumptions from the authors side may cause an exaggerated total number of vibrational hours and cost.

It is still the authors opinion that when seeing the low number of "general cargo"-ships that do other operations than Discharging, Loading or the combination of these purposes in the *Port of Sandnes* and *Sandnes Havneterminal AS*. A reason why the terminal in the *Port of Sandnes* has been chosen as a case is that it is easily identifiable in the data collected from SafeSeaNet Norway(SSN-N), as it has the unique terminal location code NOSAS (Unlocode) not used by any other terminals. For other destinations the voyage data contains a with a Unlocode shared by several terminals, making it hard to pinpoint the exact terminal visited by the ships. This in turn makes the study more precise in term of who were looking at over other locations where we would not be able to determine the terminal actor.

The cost of later departing ships may also have substantial sequential costs, like the cost of having mobilised people for x-number hours and the ship's early departure does not change the fact that the people have been mobilized and still have a cost for the port unless they can be used for other tasks instead. In the example for a departing ship being late, there may be sequential cost of waiting time for the terminal crew working overtime or that an another ship may have to wait which in turn creates "ripples" of sequential changes, where the terminal crew had to be shifted from other tasks which in turn has a later start up and the potential costs that this can create (E.g. the third ship must be manned by an overtime crew or tasks done in the terminal for other customers than the ship are affected by such "ripples"). All in all, the author has the opinion that the general findings are correct and that the uncertainties these factors are causing uncertainties within the limits of tolerance. The author has also tried to be conservative by always using the lowest number or using ranges when doing the calculations. Nonetheless, future studies may be more accurate when applying above mentioned the filters and differentiates between the different types of vibrational costs. What is certain is that the uncertainty has increased to the calculation of the total number of deviation hours and in how to calculate the total cost using such a method. And there may be other flaws which the author has not been able to discover. This in turn does create the possibility for the findings to be wrong, even if the author means otherwise at this given point in time.

5.2 New methods can make cargo transportation in North Jæren more profitable (H1)

After some time used one of the main discoveries in development of this master thesis was the discovery that that variance of ship arrivals and departures is one of the common sources of wastes in the terminal operations (4.1.1 "Ishikawa" / Fishbone diagram: Cause – Effect analysis) when doing "*conventional general cargo*" operations from ships doing that type of operations (E.g. crane, fork lift, stuffing/stacking, terminal transport and other operations connected to goods handling).

By using different tools from TQM and Lean meth ology, the author has tried to find new methods that can remove variance to the supply chain and in particular for the interaction between land and sea. Some other methods both for "inland" and "transport methods" were also considered but fall short of the method proposed that had the highest effect for not only the terminals and the ships, but for the whole supply chain, namely the new method of creating a *"Information sharing HUB (Ship - Port - Hinterland)"* by using TQM and Lean tools in a never ending continuous improvement loop like the one of Kaizen. The result was that of a subjective selection based on subjective "brain storm", as described as one of the TQM tools by Heinz and Render in their book *"Operations Management – Sustainability and Supply Chain Management"* (Heizer and Render, 2014). As a result, the author could weigh the alternatives from the brain storm and come up with the at time "best" looking solution. The usage of subjective meanings and the cognitive limits that such an approach has must be taken into consideration when concluding. As the author earlier has discussed the findings may be different at a later time and place and can be refuted due to the fact that the scores given are based on subjective inputs and meanings. The author therefore tried to visualise the effect of the variations seen from the port and terminal side, on how many hours of waste and the cost these deviation hours could amount to. The method of doing so is the same as the first step of the continuous improvement circle of "Kaizen". By analysing the data from SafeSeaNet, there was definitely possible to observe that there is variance to the ships and terminal operations in the case of "Sandnes Havneterminal AS" which also through interviews with the employees in the terminal was subjectively confirmed. Other maritime experts were also interviewed, like Johannes Tandrevoll in the Port of Stavanger and as well as Inger Tellefsen from the Sea division in Kartverket (The Norwegian Hydrographic Service), made a point of that "weather" is the biggest factor coming to deviations of ship arrivals and departures. The author has not looked at the correlation between weather and ship voyages, but acknowledges that this may have a big impact on these deviations. Non the less by using the new tools described above, the **hypothesis is proven to be true using** the authors inductive method, using the "Sandnes Havneterminal AS" findings to say something about the whole of North Jæren (and Rogaland county). The criticism is that we cannot prove this with 100% certainty by only "visualising the problems" of deviation, without going through the whole loop of "Kaizen" seen in *Figure 10* on page 35. The hypothesis is thus subjectively proven to be true, which mean that this can be refuted if someone can find other methods or can visualise other major deviances from what the author has done. The data set used for the visualisation is also only 16 months of data, so there may be too few data to conclude as have been done above. I addition the confirmations done by unstructured interviews are also a product of the interviewed persons own opinions and experience, as well at the interpretation and the ways the questions were put forward by the author influences the results and verification of the hypotheses in this master thesis.

5.3 Changes can contribute to new cargo transportation in North Jæren

One of the findings from the hypothesis one (H1) was that without having the opportunity of going through a full "continuous improvement circle of Kaizen" (*Figure 10*, pg. 6) many times, the hypothesis is proposed tested by simulating in a control chart diagram that historical update data could prove that the use of Lean and TQM methods in addition to the new method of building a *"Information sharing HUB (Ship - Port - Hinterland)"* that enables better JIT ship and terminal operations by the usage of such a tool. The method uses historical data and is as such not responding to any changes, which can be done when using the whole "Kaizen circle". This limits the hypothesis testing to "dummy" testing on old data, but should give a good enough indication on weather updating intentions (Estimates) of arrival and departure times (ETA/ETD) will help when using TQM and Lean tools and methods included in the new method described above.

When following the method described in chapter 4.7 above, **the second hypothesis (H2) is proven to be true using** the authors method of doing tests by using historical data and with the reservations mentioned above.

5.4 The findings

During the work leading up to the final hypotheses tests, there were a number of additions not related to the theses added. The hypotheses were originally limited to looking at Rogaland, but then was narrowed in to the North Jæren area. The maritime research of the author drew the attention of the developer of the Sea Traffic Management/PortCDM concept and the Port Call Message Standard/Format. This caused the attention to again be drawn towards the "big numbers" that were available for the whole of Rogaland County in the SSN-N dataset. This in turn has made the intention of hypothesis one (H1) to look up on the whole county using inductive reasoning a side product of this, and as written earlier has done that parts of this thesis has been published in an article with the author of this master thesis being one of the co-authors in a paper that was published on the 18th of march 2018 that uses the findings of the Rogaland deviations as basis for the discussions and calculations on a world wide scale. Even so the master thesis still maintaining the focus of the region of North Jæren, which was the intended goal of the inductive method and reasoning in the first place.

The new tools described above, the **hypothesis is proven to be true using** the authors inductive method, using the "Sandnes Havneterminal AS" findings to inductively say something about the whole of North Jæren (and Rogaland county). As said earlier the deductive method generalises from some observations to all observations and the subjective approach used both for the first and in the second hypothesis, using among other things subjectively driven findings from brain storm principles and interviews, makes the proven hypotheses open for criticism and refutation.

None the less the findings are drawing in the direction of that some of the findings, like the findings around the number of ship arrival and departure deviation hours, are hard to deny. There may be much of the deviation that can be dedicated weather conditions, but still it is certainly much that can be done on operational levels if correct and trustworthy information comes in time for the terminals, and the rest of the supply chain to do changes in their own operations. The author has no doubt that the terminals and ships are doing their utmost with the technology and methods available to avoid deviations, but this can be done better in using TQM and Lean tools and methods in combination with new information sharing platforms, like the proposed new method of *"Information sharing HUB (Ship - Port - Hinterland)"*.

5.5 Suggestions for future research and work

In the course of the writing of the master thesis there have come up many fields which the author has not been able to follow up on, but that future research and work could help solve. Below some of the fields to study are briefly described.

The Port of Sandnes / Sandnes Havneterminal AS

The *Port of Sandnes* has been very helpful in providing and sharing their own knowledge. All of this increases the quality of the master thesis paper, and increases the value of this paper not only for the *Port of Sandnes* their Terminal but also for the rest of the maritime business.

As we discussed in chapter 1.3.2 and 1.4.2 the *Port of Sandnes* still sees itself influenced by the sequela of the rapid oil price fall in 2014 and the negative effects more than three years after even when much of the export industries are thriving due to a weak Norwegian currency (NOK). Another uncertainty momentum for the port is that they in 2018 are moving away from some of the inner terminal areas due to urban development, the effect of this is fewer quays to operate to and from for the ships. This may affect the logistics in new ways and if there is a lack of available space or hinterland infrastructure this may create strain on the Terminal operations or new bottle necks which must be managed and mitigated.

- Perhaps it is possible for others to do research on this when these changes have been implemented. In time to come it would be very interesting to have some results from a before and after study. The *Port of Sandnes* is most certainly aware of these challenges and uncertainties.

Another aspect which makes the study of the *Port of Sandnes* very interesting is that the terminal/port is paid per ton of cargo moved over the quay front (10.00 NOK/ton)[16] with no hourly prices or defined time constraints to when cargo operations are supposed to be finished. It is according to the interviewed at the terminal, only in special cases that an extra truck or stevedore (Person employed at a dock to load and unload ships) is invoiced extra. The ships also pay a fixed quay rental price based on the size of the ship at 1.00 NOK / per gross tonnage per day.

Most ships thus pay a fixed sum for cargo operations and have fixed prices for staying at the berths for full days. Delays of less than 24 hours usually does not cost the ships extra fees and only matters for them if shipping contracts are "broken" triggers penalty fees for delivering or picking up goods to and from other ports later than agreed upon. The variation costs are thus almost in its entirely carried by the terminal and port and by not the actors causing the actual delays.

This does not make the *Port of Sandnes* unique in any way, there are many ports paid similar for same services, but this shows us that there is no clear incentive to shorten cargo operations or berth stays seen from the "ships perspective" and the port has very limited possibilities to invoice extra costs ship arrival or departure variation.

- This may have to be changed in creating new incentives or having possibilities for sanctions for arriving ships. This is of course a discussion and decision that the ports and terminals have to take themselves.

The goods owners

There are many reasons for late or early departures, waiting for bunkering, repairs/repair parts, late arriving goods, crew change, pilot boarding or other services from the onshore side. In some cases, the ship has a contract with the freight forwarder or the consignee which penalises the ship if it is too late. All of these are involved in making a service that the customers want to pay for.

- How can the goods owners and the buyers of goods and services be involved in the whole value chain? They may not be one of the local actors but big companies abroad.
- How can their needs be covered in the future and which tools and methods are they using today? Perhaps can we in the maritime business learn from them, to give the increased quality they want from our services.

[16] Taken from the 2018 price list of the *Port of Sandnes* on https://www.sandneshavn.no/havn/priser

"Information sharing HUB (Ship - Port - Hinterland)"

As the master thesis is limited to observing historical data, and not that of data done by continuous improvement, it must be the task of the terminals themselves and future studies to calculated how much we actually can reduce this, the author can only speculate around this. Unless there is a willingness from the management to invests in new methods, TQM and Lean tools, there may never be the opportunity to mitigate waste or show that these methods and tools have positive effects. By using TQM and Lean tools, these costs should be able to lowered for ports and terminals. How much it can be lowered are only speculative if the real causes of deviations cannot be found.

The author thus recognises that without further studies, and the commitment of the whole value and supply chain. There may not be a near future for the use of new methods and tools and there may not be enough proof to say that these findings are correct. The initial findings of this master thesis around deviations to the ships needs more research.

The ships deviation has been visualised, and the potential savings, but the causes have not. The future studies should look into if

- There is seasonal variation?
- There are the holidays or weekends important in understanding the deviations?
- Operational sequences have an impact on deviation? (E.g. pilot boarding, cargo from hinterland)
- There are any bottlenecks and where they are?
- Can more IT systems be connected in m2m operations?
- Does information sharing mitigate variance?

In the master thesis it has been stated that we only look at the variance from ship to terminal or port operations within the ports and terminals. What the costs for the rest of the value chain is (truck drivers, goods owner, end user and others). Also here we can only speculate on the "wasted hours" and costs, but these could be huge due to the fact that goods may have many stops underway to their final destination and the variance in one part of the value and supply chain may have big impacts on other parts of the chain and should be looked into in future studies. This should also be looked into.

5.6 Recommendations

As a final recommendation the author future research to make a "drill down" in similar data to that for *Sandnes Havneterminal AS* / The *Port of Sandnes* (NOSAS) for other ports and terminals. To be able to do so and to have a tracking of historical and live data in TQM and Lean tools like the Control chart used in the testing of hypothesis two (H2), we need data.

It is important for visualising trends and to see if actions taken by the operation managers are correct or if they need to change their approach to solve the problems. As seen and visualised in the research done, variance plays a big role in the ports and terminals operations not only on the ship side bus also from services and goods coming from the hinterland.

When looking at only the sea side, we may lose the focus on other parts of the whole "picture". Therefore, the data collected should not only be constrained to the ship side, quality is as much a service coming from the other parts of the value and supply chains.

When saying that we need data, data is not only data. There are issues about the quality of data, too much data or too little data. If it is used falsely, we will not have any use of the data.

If we are not aware of this, this in turn also creates "wasted time" and "wasted money" because the data either was wrongly used or had a bad quality. By looking at the SSN-N data there was much information available but it was only a fraction of the data that had actual and estimates which could be used in the "cases" discussed in this master thesis.

A last "pep talk" and recommendation to terminals, ports or other actors interested in how maritime operations are affected by deviation, is that they need to collect the historical data, from the first registrations and all the updates along the "notification timeline". If we only can observe static point in time, like the latest estimate, we cannot compare all observations against each other and against the actual observation. The study of the SafeSeaNet Norway data showed the importance of having such data.

6 Conclusion

The starting point of the creations of the hypotheses was the authors wish to look into if *"New changes can help the maritime business to achieve better quality and reduce "waste" and thus enhance the customer value of their services?"*

The author has found by using the TQM and Lean theory, methods and tools we are able to visualise and can mitigate or remove the negative effects of variance on quality and increase the profits for the maritime business as put forward in the Hypotheses. The author has visualised the total impact and potential cost that can be saved from some ship types under the given method used in this master thesis.

How much of the cost that actually can be removed by removing causes of variance for the ports and terminals using TQM and Lean, would be speculations from the side of the authors side, but it should amount to a considerable amount when looking at it in a 5 year or longer perspective. The author hopes that future studies are able to calculate this and if possible prove how much can be saved using TQM and Lean.

As said earlier by investing in TQM and Lean in combination with the new method of a "Information sharing HUB (Ship - Port - Hinterland)" there are considerable savings to ports and terminals if there is commitment to do so. If the whole supply chain gets involved, as the TQM method proposes, the operations in the terminals and ports done by themselves is probably only a fraction of the total costs of the whole value chain. Knowing that variance usually have considerable cascading effect downstream (or upstream) in supply and value chains the author proposes that the terminals and ports should take action. The ports and terminals should avoid "silo thinking" and make contact with all the actors in the supply chain to mitigate and govern risk due to variance of all kind. If SSN-N can be the starting point of the creation of the proposed hub, needs to be looked into. A national system would as the author sees it contribute not only for the North Jæren or Rogaland county but for all regions in Norway and perhaps be an example for the rest of the world to follow.

The biggest long term gains from mitigating and removing causes of variance, is that this generates extra capacity. For terminals and ports, this means that the employees can do other tasks, ware houses can be used more efficiently which can be used for handling new or more goods. Changes can thus contribute to new cargo transportation in North Jæren (H2).

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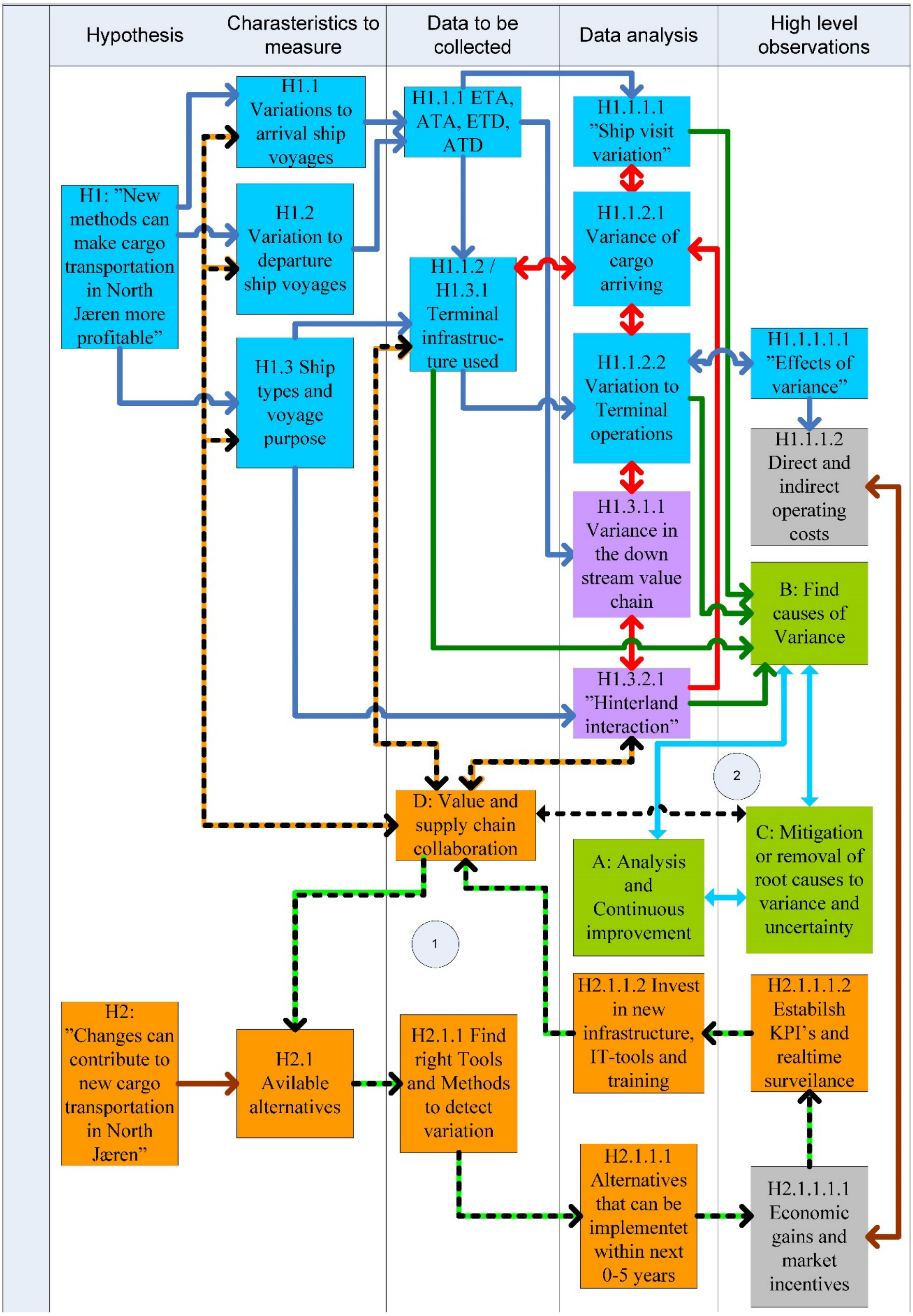
Appendices

Appendix 1 – Figure 14 "Going from hypothesis to high level observations"

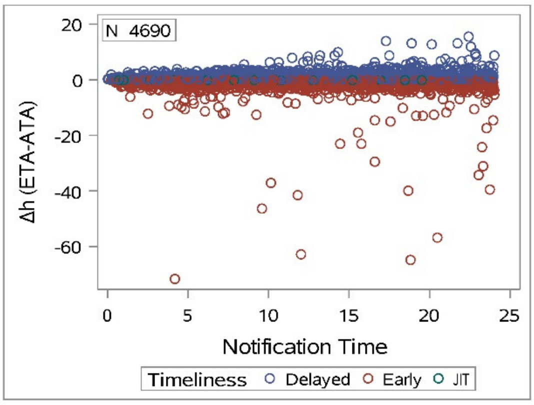


Appendix 2 – Legend: Figure 14 "Going from hypothesis to high level observations"

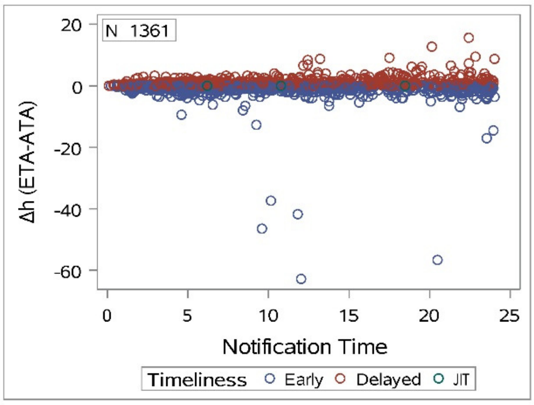
Symbol / colour	Description
(Blue background)	The hypothesis H1's "path" to high level observations
(Lavender background)	Hinterland / Downstream value and supply chain
(Orange background)	The hypothesis H2's "path" to high level observations
(Grey background)	Economic results and incentives for change
(Green background)	Variation detection, mitigation and continuous analysis and improvement
(Dark blue line w/Arrow)	Ship voyage variation and "downstream" effects
(Red Arrow w/Arrow)	Hinterland supply chain and "upstream" effects
(Brown line w/Arrow)	Hypothesis H2's characteristics to measure / cost from effects of variation
(Light blue line w/Arrow)	Direction of continuous improvement loop
(Black dotted line w/Arrow)	Link between Stakeholders and the continuous improvement loop (Operational link / control)
(Black and orange dotted line w/Arrow)	Value chain real-time collaboration and data sharing
(Black and green dotted line w/Arrow)	Infrastructure, support functions and human resources
1 (Loop number 1)	Collaborative loop: stakeholders supply and Value chain + internal resources. Reduce variance, waste (Muri, Mura, Muda), increase quality
2 (Loop number 2)	Continuous improvement loop Plan-Do-Check-Act / Kaizen
The direction of the arrow(s) shows where the information or information logic moves.	
H1.1.1 and H2.1.1, A, B, C, D are examples of the elements label/numbers for possibility of back-tracking to these elements inn later text.	

Appendix 3 – Scatter plot Arrivals

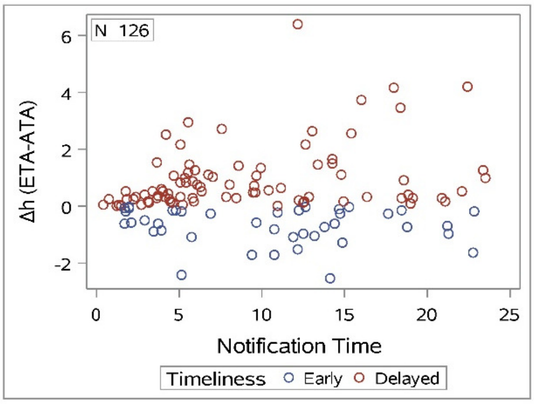
Rogaland County - Arrivals



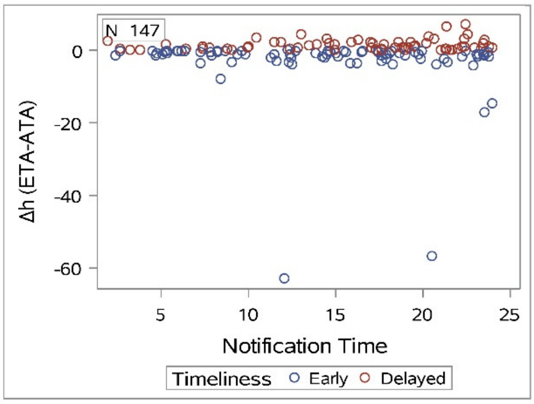
North Jaeren Region - Arrivals



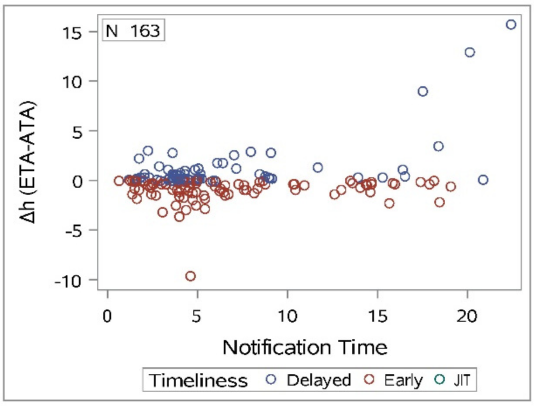
Dusavik (NODUS) - Arrivals



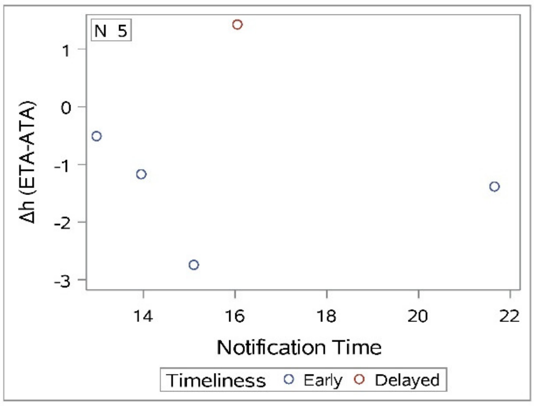
Port of Egersund (NOEGE) - Arrivals

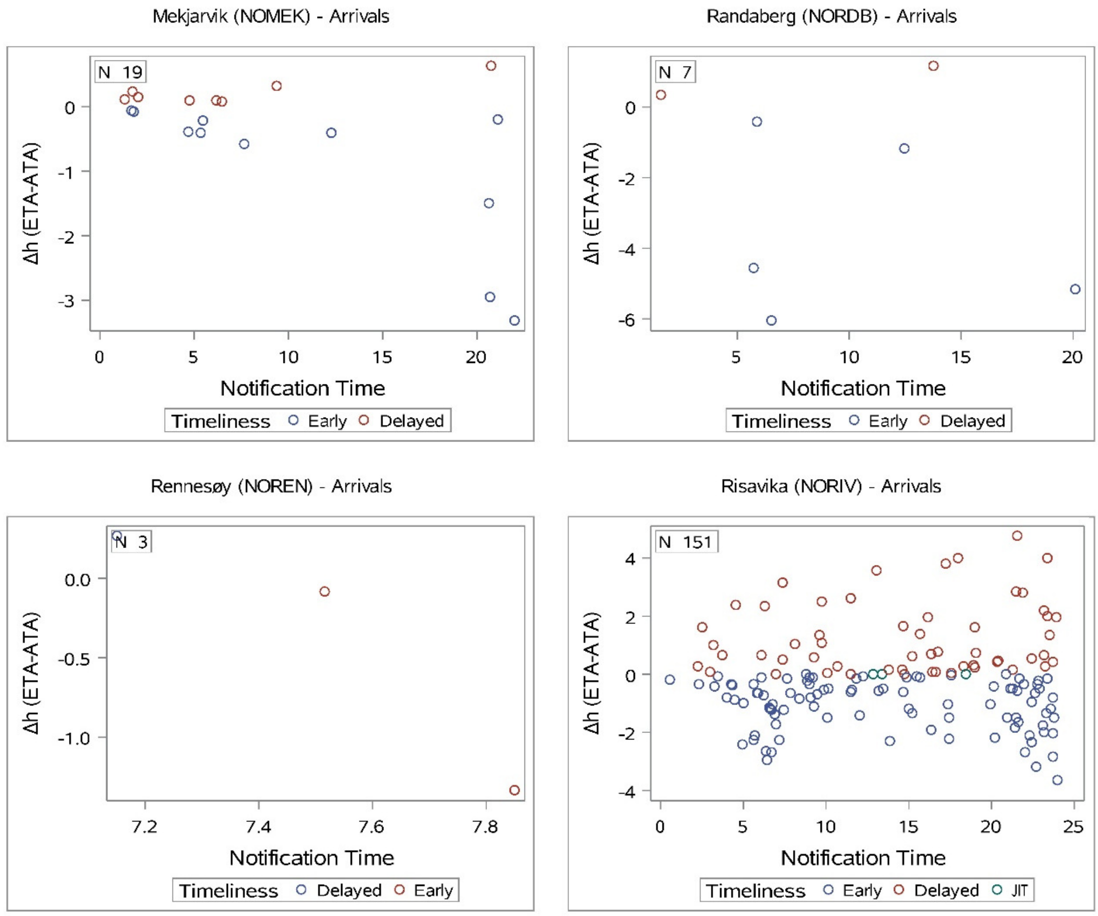


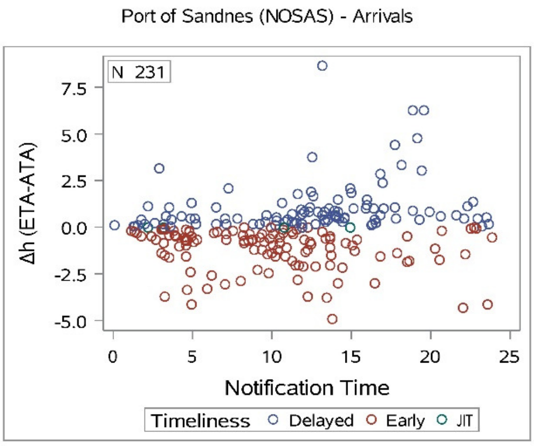
Forus (NOFRS) - Arrivals

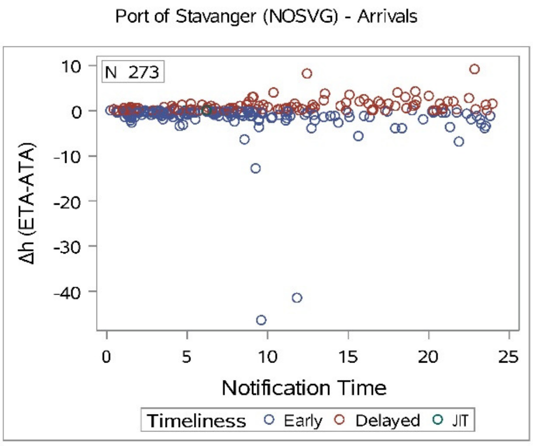


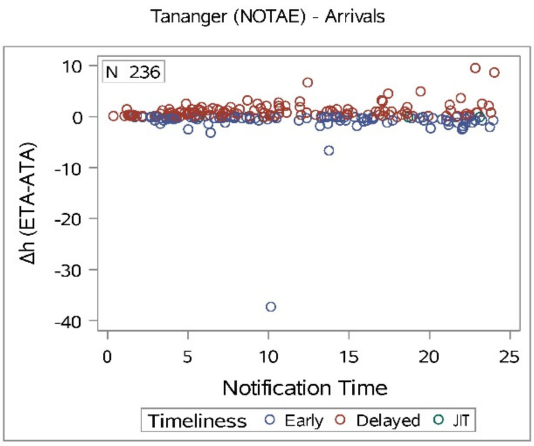
Hafrsfjord (NOHFF) - Arrivals




Mekjarvik (NOMEK) - Arrivals
N 19
Δh (ETA-ATA)
Notification Time
Timeliness Early Delayed
Randaberg (NORDB) - Arrivals
N 7
Δh (ETA-ATA)
Notification Time
Timeliness Early Delayed
Rennesøy (NOREN) - Arrivals
N 3
Δh (ETA-ATA)
Notification Time
Timeliness Delayed Early
Risavika (NORIV) - Arrivals
N 151
Δh (ETA-ATA)
Notification Time
Timeliness Early Delayed JIT

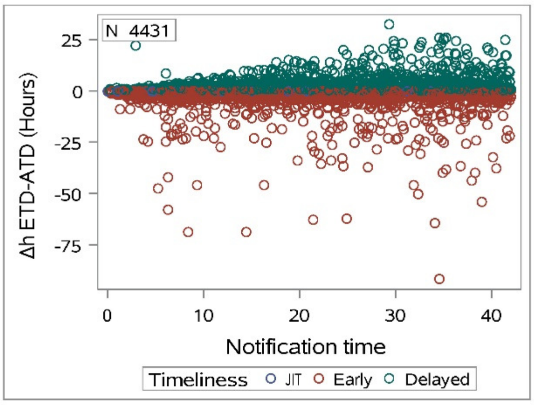

Port of Sandnes (NOSAS) - Arrivals
N 231
Δh (ETA-ATA)
Notification Time
Timeliness Delayed Early JIT


Port of Stavanger (NOSVG) - Arrivals
N 273
Δh (ETA-ATA)
Notification Time
Timeliness Early Delayed JIT

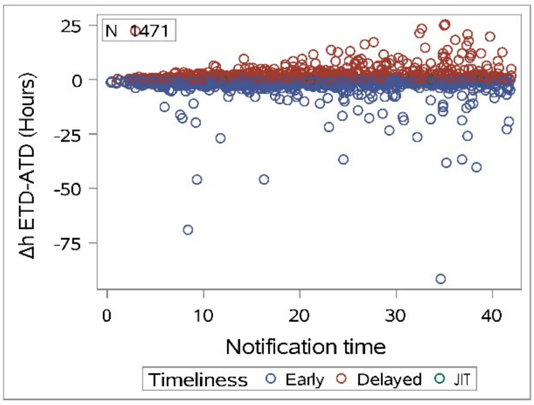

Tananger (NOTAE) - Arrivals
N 236
Δh (ETA-ATA)
Notification Time
Timeliness Early Delayed JIT

Appendix 4 – Scatter plots Departures

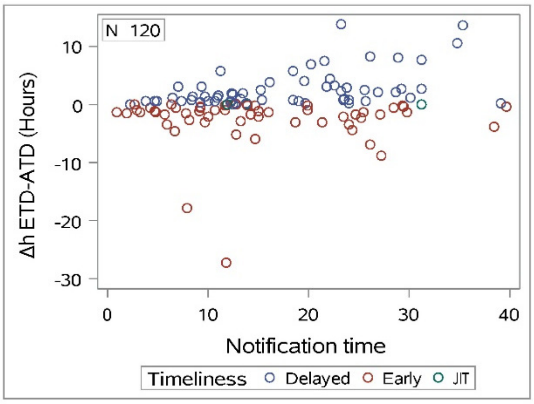
Rogaland County - Departures



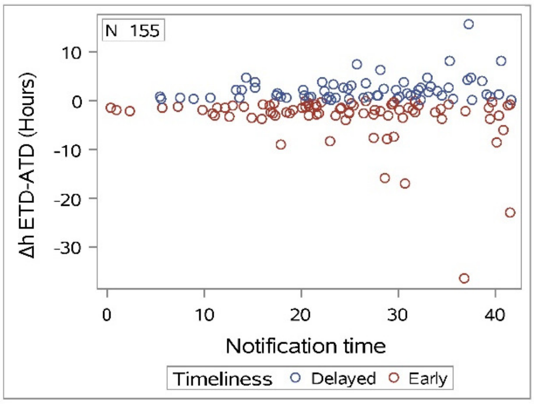
North Jaeren Region - Departures



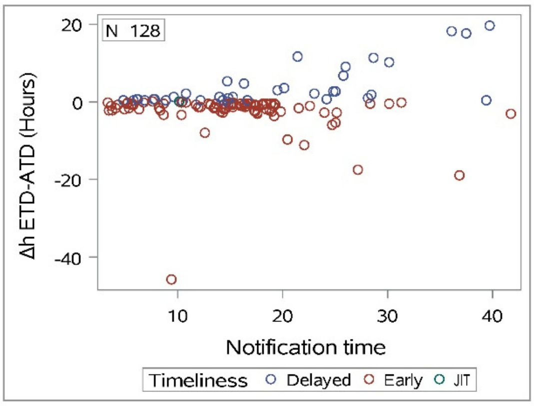
Dusavik (NODUS) - Departures



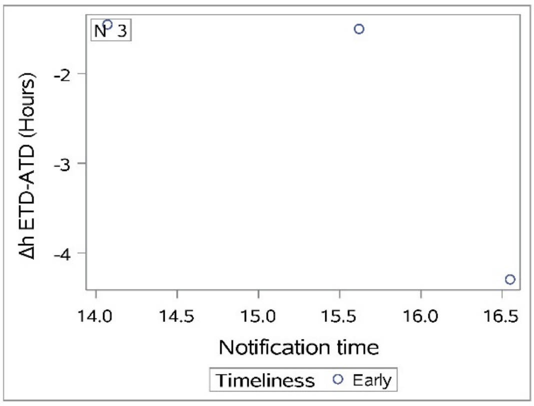
Port of Egersund (NOEGE) - Departures

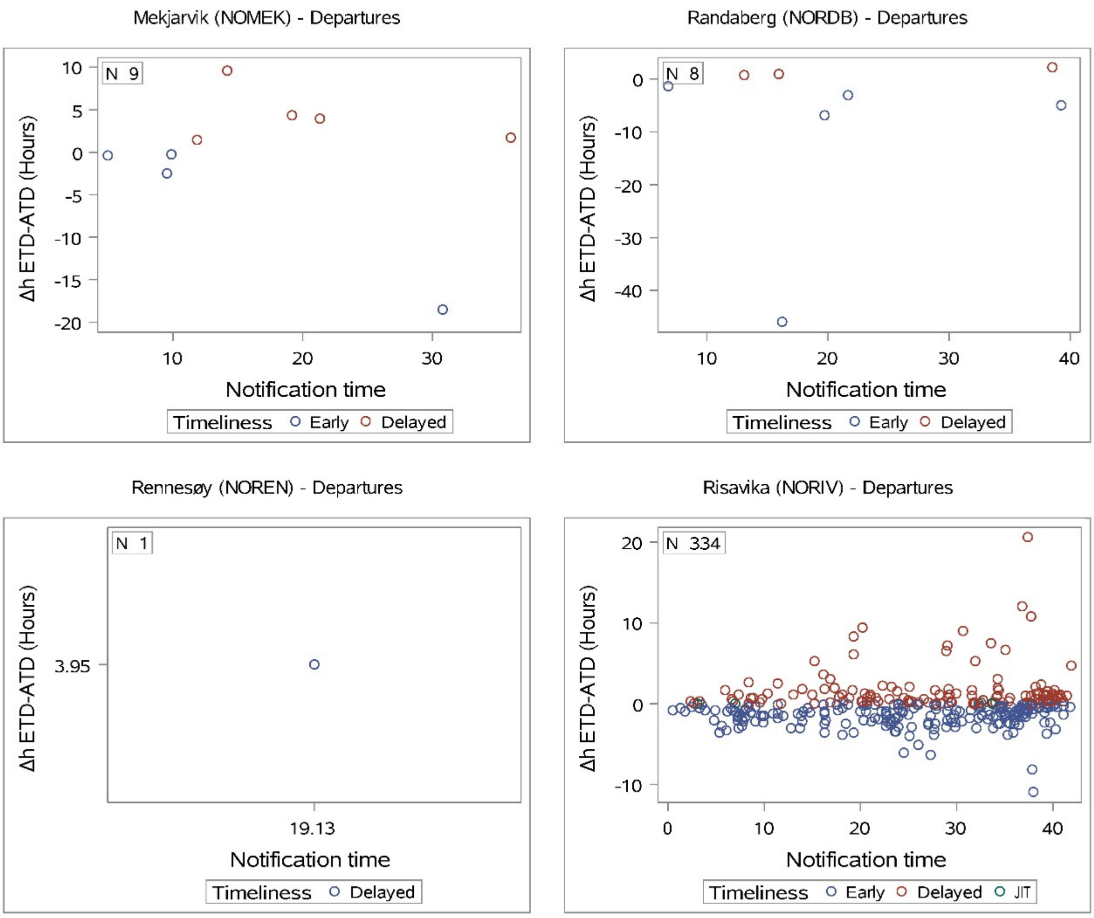


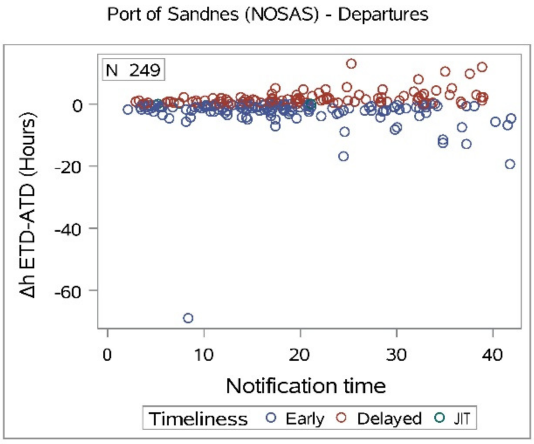
Forus (NOFRS) - Departures

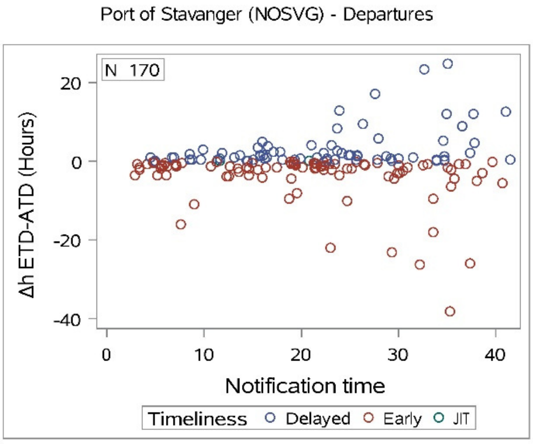


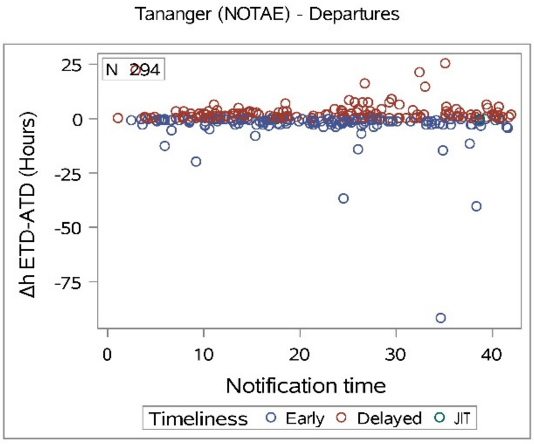
Hafrsfjord (NOHFF) - Departures




Mekjarvik (NOMEK) - Departures
N 9
Δh ETD-ATD (Hours)
Notification time
Timeliness Early Delayed
Randaberg (NORDB) - Departures
N 8
Δh ETD-ATD (Hours)
Notification time
Timeliness Early Delayed
Rennesøy (NOREN) - Departures
N 1
Δh ETD-ATD (Hours)
3.95
19.13
Notification time
Timeliness Delayed
Risavika (NORIV) - Departures
N 334
Δh ETD-ATD (Hours)
Notification time
Timeliness Early Delayed JIT


Port of Sandnes (NOSAS) - Departures
N 249
Δh ETD-ATD (Hours)
0
-20
-40
-60
0
10
20
30
40
Notification time
Timeliness
Early
Delayed
JIT


Port of Stavanger (NOSVG) - Departures
N 170
Δh ETD-ATD (Hours)
20
0
-20
-40
0
10
20
30
40
Notification time
Timeliness
Delayed
Early
JIT


Tananger (NOTAE) - Departures
N 294
Δh ETD-ATD (Hours)
25
0
-25
-50
-75
0
10
20
30
40
Notification time
Timeliness
Early
Delayed
JIT

Appendix 5 – Calculations deviation hours Arrivals

ROGALAND County - Deviation Time Arrivals (Total hours)	N	Standard deviation	Mean	Min	Max	Sum Hours of Deviation
Delayed	2263	1.362719	0.983621	0	15.72	2225.933
Early	2375	3.782007	-1.39419	-71.7833	0.00	-3311.2
JIT	52	0	0	0	0.00	0

ROGALAND - Deviation Time Arrivals (Total hours)	N	Standard deviation	Mean	Min	Max	Sum Hours of Deviation
Delayed	2263	1.362719	0.983621	0	15.71667	2225.933
Early	2375	3.782007	-1.39419	-71.7833	0	-3311.2
JIT	52	0	0	0	0	0

NOSAS - Deviation Time Arrivals (Total hours)	N	Standard deviation	Mean	Min	Max	Sum Hours of Deviation
Delayed	104	1.396533	1.038942	0	8.65	108.05
Early	123	1.085315	-1.16951	-4.93333	0	-143.85
JIT	4	0	0	0	0	0

Appendix 6 – Calculations deviation hours Departures

ROGALAND - Deviation Time Departure (Total hours)	N	Standard deviation	Mean	Min	Max	Sum Hours of Deviation
Delayed	1845	3.864123	2.698094	0.016667	32.41667	4977.983
Early	2507	6.298805	-3.07278	-91.8167	-0.01667	-7703.47
JIT	79	0	0	0	0	0

North Jæren region - Deviation Time Departure (Total hours)	N	Standard deviation	Mean	Min	Max	Sum Hours of Deviation
Delayed	628	3.573775	2.428822	0.016667	25.43333	1525.3
Early	823	6.091597	-2.78483	-91.8167	-0.01667	-2291.92
JIT	20	0	0	0	0	0

NOSAS - Deviation Time Departure (Total hours)	N	Standard deviation	Mean	Min	Max	Sum Hours of Deviation
Delayed	103	2.369329	1.964563	0.033333	12.95	202.35
Early	143	6.325361	-2.82273	-69.0333	-0.03333	-403.65
JIT	3	0	0	0	0	0

Appendix 7 – Balancing just-in-time operations – Coordinating value creation

SEA TRAFFIC MANAGEMENT

17th of March 2018
(Concept note #6)

Balancing just-in-time operations – Coordinating value creation

by

Mikael Lind[1, 4], Terje Rygh[2], Michael Bergmann[1], Richard T. Watson[1, 3], Sandra Haraldson[1], Trond Andersen[1, 2]

[1]RISE Viktoria, Sweden, [2]Port of Stavanger, Norway, [3]University of Georgia, USA, [4]Chalmers University of Technology, Sweden

The knowledge society

Decision-making is the central activity of modern society, and high-quality decision-making is based upon a trifecta of data, information, and knowledge. A knowledgeable person requests information to enable decision-making. To fulfil the request, data are converted into information. Personal knowledge, which includes expertise, is then applied to interpret the requested information and reach a conclusion, as shown in Figure 1.

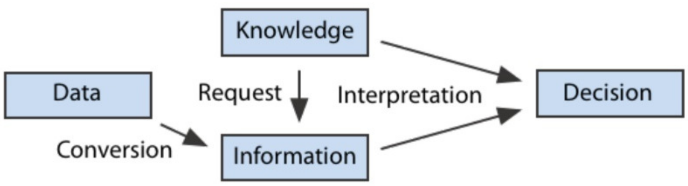


Figure 1: *The relationship between data, information, and knowledge*[1]

The shipping industry has the same need as all participants in competitive economies to make high-quality decisions. However, because it is a self-organizing ecosystem, there can be a lack of data for the involved stakeholders when individual actors don't share plans and outcomes. As a result, the quality of decision-making is lowered.

As elaborated in earlier concept notes in this series, digitization enables the creation of systems of record[2] that others could use to optimize port operations for the benefit of the whole ecosystem. Shared data can also establish a basis for creating flexibility to manage disruptions. High-quality decisions are based upon having adequate data to fully understand and analyse a problem or situation.

[1] Watson, R.T. (2013). *Data management: databases and organizations* (6th ed.). Athens, GA: eGreen Press.
[2] Lind M., Bergmann M., Haraldson S., Watson R.T., Park J., Gimenez J., Andersen T. (2018) Enabling Effective Port Resource Management: Integrating Systems of Production Data Streams, STM Validation Project

Co-financed by the European Union
Connecting Europe Facility

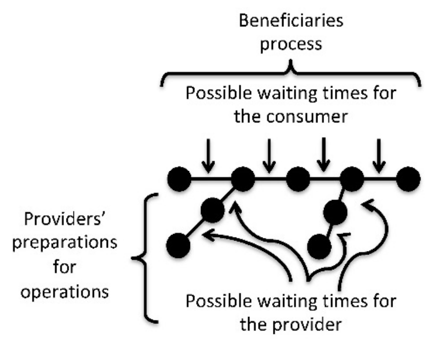
17th of March 2018
(Concept note #6)

In a self-organized ecosystem, there is no natural leader; each actor is highly dependent on enhanced collaboration among involved actors. In order to cater for a fruitful collaboration, actors need to share their plans with each other to improve each other's decision making for the benefit of the common object of interest shared among the actors.

Port operations is an area where there is an opportunity to pursue enhanced coordination based on a ship's berth-to-berth progress. In such operations, there is often a strong desire to enable short turnaround times for visiting ship, but also for actor's actions alignment in their service operations. Both for the service provider and consumer, there is a need to avoid waiting times. Just-in-time actions enhance consumer satisfaction as well as improve resource utilization.

In this short concept note, we use data from a region in Norway, the Rogaland County, to reveal the improvement potential enabled by Port Collaborative Decision Making (PortCDM) based on actors sharing their systems of record. This analysis shows the direct effects of applying PortCDM as an enabler of Sea Traffic Management (STM) for efficiency, safety, and environmental sustainability in berth-to-berth sea transport.

The two sides of just-in-time operations



A ship is ideally served just-in-time for the different events, episodic tight couplings, that constitute a port visit. Just-in-time operations mean zero waiting times for a ship and the shore stakeholders. Each actor performs its actions/operations just-in-time. This will typically require that the service providers have some slack resources since a port is a system of production, somewhere between a factory and a job shop. The arrival of ships and their service needs will vary, and just-in-time ship handling requires slack resources to handle this variation.

A single port call can be associated to the Toyota Production System when it comes to the desire to cut lost time. Toyota strives to reduce waiting time and has a high focus on process optimization. Port operations should be able to benefit from this way of thinking and by the concept of PortCDM able to reduce "muda", which is a key concept in the

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LEAN process of thinking as well as the KAIZEN concept of constant process improvement.

Pilotage, as a part of the port call process, is an illustrative example of enabling just-in-time ship operations. The ultimate goal should be that the pilot is available when a ship arrives at the pilot boarding area. Neither the ship (as the service consumer) nor the pilot (as the service provider) should have to wait for each other. However, this might mean that pilot resources are not fully 100% utilized in order to ensure that ships do not wait.

As the mantra of today's business practice is to put the customer in focus this means that the needs of the service consumer (the shipping company) typically overrides the needs of the service provider. Higher accuracy planning data, timestamps, expressing intentions shared among all actors providing services to the common object of interest, creates the potential for service providers to plan their operations to optimally meet the needs of the service consumer, without any unnecessary waiting times for the consumer. In other words, service providers should aim to minimize their slack resources.

Enhanced data reliability: The core of the PortCDM concept

The concept of Sea Traffic Management (STM) covers data sharing in a berth-to-berth voyage to enhance efficiency, safety, and environmental sustainability of sea transport. STM has brought forward the enabler, Port Collaborative Decision Making (PortCDM) to contribute to enhanced coordination and synchronization of port call operations. PortCDM builds upon sharing time stamps between different port call actors as the basis for:

- providing enhanced accuracy of essential timestamps in the port call process
- providing a basis for each port call actor to align its plans of their operations
- establishing a continually emerging common situational awareness among involved actors

Common situational awareness is a reflection of the content of the current systems of record concerning a particular port call at a particular time. This also means that when the system of records captures plans, or their realization, of events in the systems of production, situational awareness will be updated. By established a communication channel for updating each other in real-time, port actors can maintain an accurate situational awareness.

Since event changes in the system of production are instantly captured and shared in the system of records, it is possible for an individual actor to be notified of desired event

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changes, such as the ship arriving to the pilot boarding area, and also be informed of possible deficiencies in the overall plan of the port call process. Within PortCDM, an indicator system, from which actors can get warnings, has been defined for three different types of states, as configured by the actor:

- missing data, which directs attention towards possible missing data in the system of records based on when they should have occurred in a system of production. One example is a pilotage need requested and confirmed some pre-defined hours before arrival.
- conflicting data, which directs attention towards actor's different conceptions of timestamps. An example is when port authority, the terminal operator, and the captain report different estimated times of arrival to berth.
- unreasonable relationships, which directs attention towards the relationships between different timestamps. An example is when the time between estimated times of pilotage commenced and arrival at berth differ outside a defined range

The case of Rogaland County[3]

Rogaland County is the third biggest maritime economic region in Norway only surpassed by the Oslo-fjord and Bergen region. It is situated on the southwest coast of Norway. Some of the major ports and terminals/terminal operators located in Rogaland are Stavanger, Karmsund, Egersund, Sandnes, Kårstø (Statoil), Westport, NorSea (Dusavik/Tananger), ASCO and Kuehne & Nagel.

We examine conventional cargo operations in Rogaland, and concentrate on the ship types mostly used in those types of operations. The study reports on ship types of "General Cargo Ship", "Ro-ro Cargo Ship", "Refrigerated Cargo Ship", "Palletised Cargo Ship" and "Container ship". Ship types uniquely transporting "Dry bulk" and "Wet bulk" ships are as such also not included in the studies. The case is based on a data sample from 16th of June 2016 till 24th of October 2017 (16 months). These data, containing only notifications done in the 24 hours prior actual arrival, are summarized in the following table.

[3] The case is based on the master thesis "Alternatives for the Development of the maritime business in Rogaland" written by Terje Rygh (To be submitted 26th of March 2018).

	Number of unique port calls in the data sample (captured in NSW)	Early (total in hours)	Late (total in hours)	Total
Arrival *	4691	3311,2	2225,93	5337,13
Departure **	4431	7703,5	4977,98	12680,98
Sum (in hours)				18218,11

* Based on ETA unique message estimates

** Based on ETD unique message estimates

Within the last 24 hours of the Actual Time of Arrival (ATA) there are a total of 21 681 registrations and update messages to the ships Estimated Time of Arrival (ETA) (see figure 2 below). An average berth stay in Rogaland is of around 18 hours, we therefore look the last notification updates of ETD given in the 24h period before arrival adding the time of the average berth stay (42 hours of time line of observations prior to ATD). In the last 42 hours before the Actual Time of Departure (ATD), there are 18 356 estimated time of departure registrations and updates (see figure 3 below).

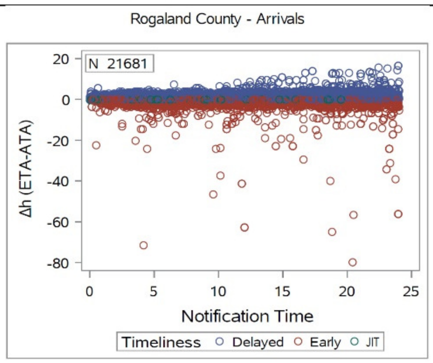

Figure 2: Arrival - Variation of ship voyage updates in Rogaland (all ship types)

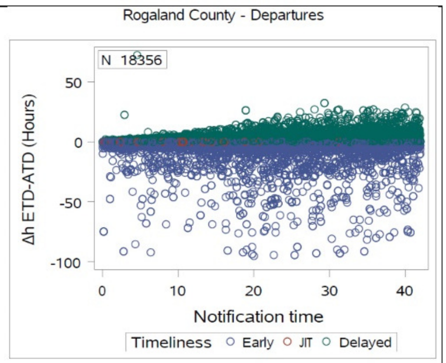

Figure 3: Departure - Variation of ship voyage updates in Rogaland (all ship types)

The two figures show scatter diagrams of ships arriving and departing berths in Rogaland County. They show ships arriving or departing *too early* (negative y-value) or *too late* (positive y-values). As can be seen from the diagrams, there are more than twice as many more instances (hours) of late departures than late arrivals as also the preceding table depicts.

Looking from a terminal operator's perspective, early or delayed ship arrivals or departures have to be managed on a daily if not hourly basis. The goal of the operations manager is to manage variance of predictability in port or terminal operations and strive for just-in-time (JIT) operations. To change the execution of one task or a series of operational sequences may be impossible due to variance, and a "bull-whip" effect may occur in the whole value chain down- and upstream. If there are no means to mitigate these variances, they might cause idle resources for the terminal operator. If the next ship in line has to agree to use earlier or later time slots, this in turn may influence other ships and terminals as well as third parties that in turn need to shift their operational plans. The ability to get early notification of late ship arrivals or departures in real time would have a big impact on a port or terminals' ability to mitigate operational variance. If handled well, situational awareness can help them, their customers, and other stakeholders in optimizing their day-to-day business.

> *"Through updated information and use of Slot Time, it`s possible for shipping companies to save up to 75% of port fee. Based on the availability of real-time information about the ship's position, it can enable the port operator to increase the utilization of resource capacity up to 40%"*, Kurt A. Ommundsen Managing Director WESTPORT AS

An analysis of the case data reveals an average loss of 5693 person-hours per month (just for the terminal operators which is just one actor group involved in a port call), and the cost of ships arriving late or early lies somewhere between USD 3 049 000 and 5 149 000 per year due to terminal workers having to wait, show up early, not having any capabilities to re-plan, or do work in another sequence. It is reasonable to assume that when taking all actors involved in a port call into consideration, the cost for ill-coordinated operations would likely be much higher for the rest of the value chain (tug, pilot, linesmen, truck drivers, goods owner, warehouses, retailers, and others).

A conservative and sensible approach would thus be to double the average loss by including all actors involved in a single port call, which gives us a saving of 6 – 10 millions USD. This equals a loss per port call off USD 350 -600. If we assume that the numbers can be aggregated worldwide (20 million calls worldwide annually) we have an annual loss of USD 7-12 billion.

For actors, such as Amazon and Alibaba, who both receive and send goods by ships, the quality of ship arrivals (predictability and punctuality) is likely a high priority. They will obviously be concerned when port variance magnifies downstream supply and value chain disruption. We speculate that these will be significant because goods can have many waypoints before their final destination, and variance in one part of the value and

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supply chains may have big impacts on other parts of them. This should be investigated in future studies.

The impact that ship arrival variance has on operational costs, as in the Rogaland case, shows why there needs to be a focus on how to manage variance. The data sample of Rogaland covers about 35% of the port calls in the region for just one actor group, the loss of person hours is significant, and consequently the are substantive possible savings. By using existing standards and tools, reducing these costs should be possible. Better situational awareness using PortCDM, in addition to advanced resource management tools, should enable ports and terminals to improve their performance. For example, using real-time benchmarking with historical data and process control charts, in collaboration with PortCDM, it is feasible to consider reducing variance costs. However, today's terminal and port operation managers do not have all the data and tools they need to make smarter decisions.

Enhanced data reliability and sharing creates business value

Accurate timestamps enable higher precision planning. This in turn drives the service provider to optimize its operations for resource utilization. A very tempting goal is optimization of berth utilization. It is common that some terminals adopt a strategy where the visiting shipping company pays the price for a 24-hour slot, when it often requires less than 24 hours to complete the service. A reasonable approach is that booking is for shorter time frames and that the client pays, possibly a higher price per hour, for the time it takes to complete the operation.

Such a change will require higher reliability timestamps throughout berth-to-berth sea transport. By adopting solutions enabled by PortCDM, actors within the self-organized ecosystem could gain higher reliability and predictability of port call events. This is also a driver for gaining more business for the port.

High quality data for decision-making is necessary for managing the trade-off between making commitments to clients versus having flexibility for managing disruptions. It is rarely sensible to plan all resources for 100% utilization, but on the other hand planning means that commitments need to be made so that the client's, expectations can be met as well as enabling service providers to ensure that their resources are aligned with those of each other to ensure an efficient port call.

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Value creation starts with data for better decisions

Just-in-time operations for ships can be achieved when the various parties have sufficiently accurate data of the necessary scope to make high-quality decisions. It starts by establishing a system of records to capture the spatial and temporal dimensions for planned and actual physical movements and service provisioning[4] throughout the value-creation process and directed towards the service consumer. Such systems of record need to capture major events in the systems of production, the value creation process, and these records need to be shared as needed to enable the journey from data to decision-making.

> *"Looking at a call as a production process, the port has a key role in delivering its own services, but also in facilitating other partners in the port. Data availability will not only increase port call efficiency, it will also be a step towards increasing predictability"*, Vidar Fagerheim, CEO, Shiplog AS"

Ports as systems of production

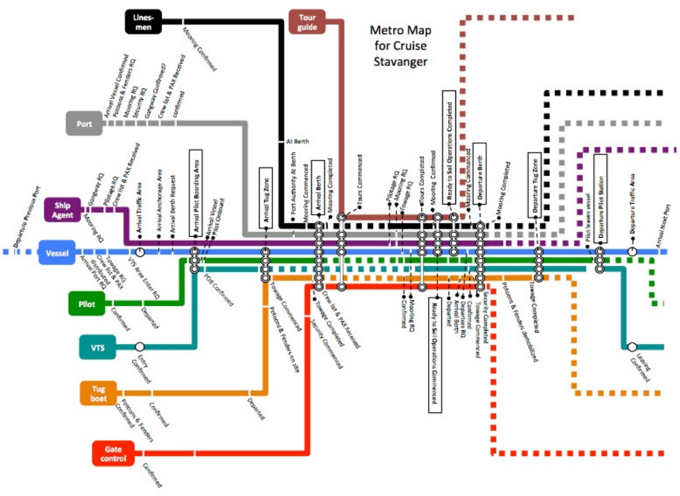

Figure 4: The port call process as a system of production[5]

A port is a collection of systems of production, one for the pilot, one for the tugs, one for the terminal, and so forth. A port visit is a sequenced dependency of each of these systems of production, and thus we can also think of the port as a system of production. A production perspective inspires thinking about methods that factories use to improve productivity and quality. Japanese manu-

[4] Lind M., Bergmann M., Haraldson S., Watson R.T., Park J., Gimenez J., Andersen T. (2018) Enabling Effective Port Resource Management: Integrating Systems of Production Data Streams, STM Validation Project

[5] *Lind M., Haraldson S., Karlsson M., Watson R.T. (2016) Overcoming the inability to predict - a PortCDM future, 10th IHMA Congress – Global Port & Marine Operations, 30th May – 2nd May 2016, Vancouver, Canada*

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facturers apply six sigma principles and lean manufacturing to raise their efficiency and quality. Goldratt's Theory of Constraints has led to significant improvements in a range of systems of production.[5] It is, we assert, time to apply management principles honed in some of the most productive manufacturing companies in the world, to ports and shipping to improve decision making and efficiency.

For more information, contact:

Mikael Lind, Activity Leader PortCDM testbeds, RISE Viktoria +46 705 66 40 97 or Mikael.Lind@ri.se

Sandra Haraldson, Activity Leader PortCDM testbeds, RISE Viktoria, +46 707 61 88 14 or Sandra.Haraldson@ri.se

Ulf Siwe, Communications Manager, Swedish Maritime Administration +46 10 478 56 29, or Ulf.Siwe@sjofartsverket.se

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[5] See Cox, J.F., & Schleier, J.G. (2010). *Theory of constraints handbook*. New York, NY: McGraw-Hill for many examples of its practical applications.

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