Robots Moving the World

A theoretical paper about optimizing the container industry through automation and robotics

A Master Thesis for MSc in Business Administration and Information Systems

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Abstract

This thesis investigates how AP Moller Terminals and Maersk Line currently conduct procedures related to unload of containers and operational container handling inside the terminals. Further, the thesis seeks to identify problems related to these procedures. The research is based on a qualitative interpretive research approach, striving to gain an in-depth understanding of how these procedures may be enhanced through deployment of Internet of Things and Software Robotic Capabilities. Through a business -and technical analytical assessment, this paper identifies a possible solution architecture that leverage on technological advancements to derive organizational benefits and drive the operational excellence of the future. The business analysis is supported by a thorough understanding of the business model and a cost / benefit analysis. Whereas the technical analysis is supported by participatory design theories and architectural frameworks.

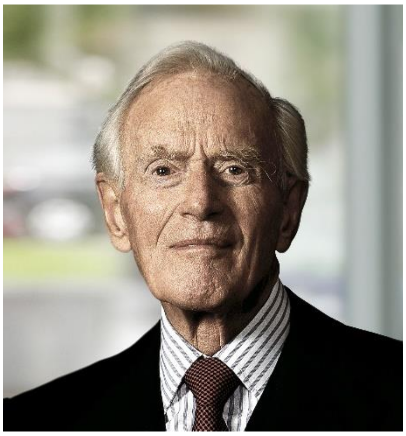
Keywords: Internet of Things, Robotic Software, Automation, Shipping, Smart Products and Services

Company Introduction

The largest shipping company in the world is a Danish company called Maersk. The Company was founded in

Svendborg in 1904 by Mr. Arnold Peter Moller together with his father Captain Peter Maersk Moller.

The two set out on a journey to enable transportation to every corner of the world. This vision of being the largest shipping company led them to create Maersk Line in 1928 which was the world's first liner service that sailed between US and Asia. In the same year Maersk also introduced its first tanker vessel to the Maersk fleet. In 1930 Maersk Mc-Kinney Moller began his training to step in his father's footprint, he worked in various shipping and banking related businesses across the globe. In 1938 Maersk Mc-Kinney Moller returned to Denmark and started in Maersk in a Junior management role.



One year later World War II broke out and in 1940 Denmark got occupied by Germany which led to Maersk sailing the entire fleet out of Danish waters and into neutral ports where the ships later would be requested to transport goods for the warring countries. Between 1940 and 1945 Maersk lost 25 ships and 150 seamen.

In 1955 the demand for shipping was growing so fast that Maersk had to increase the size of their ships. This resulted in Odense Steel building a new Shipyard at Lindø that allowed them to build ships that had a capacity up to 200.000 tons. 14 years later Maersk also outgrew this Shipyard so Odense Steel had to again increase the size of their shipyard so that they could build ships that had a capacity of 650.000 tons.

In 1965 Arnold Peter Moller passed away at the age of 88. At this point in time, the Maersk fleet consisted of 88 ships which was amounted to almost half of the total Danish merchant fleet. After the death of A.P. Moller, Maersk Mc-Kinney Moller took over the role as director of Maersk and continued to expand and develop the business. The great vision that Maersk Mc-Kinney Moller had for Maersk resulted in starting Maersk Supply Services in 1967, Maersk Airlines in 1969, Maersk Data 1970 and Maersk drilling in 1972. Especially Maersk data had a huge impact for the operations in the shipping business but the company was sold to IBM in 2004 and the business unit had at that point grown to a total staff of more than 3500 people around the world.

In 1975 Maersk introduced the first container vessels that started sailing on the original Maersk Line route from US to Asia. Throughout the 1970's containerization had expanded so much that Maersk had to establish the freight forwarder company called Mercantile with subsites in Taiwan, Hong Kong and Singapore. The activities from this company was continued in Maersk Logistics and now in Damco.

In 1979 Maersk acquired Svitzer. Today, Svitzer is the global market leader engaged in specialized marine activities such as harbor, coastal, terminal/LNG, offshore and ocean towage as well as salvage operations, crew-boat and emergency-response services. In 1987 Maersk made its first acquisition within the liner business. Maersk took over the liner activities in Chargeurs Réunis, France, and Cie Maritime Belge, Belgium.

In 1991 Maersk Container Industry was established. Maersk Container Industry was established in Tinglev, Denmark with the purpose of developing and manufacturing containers for the shipping industry. Today, the headquarters and sales office are located in Copenhagen, whereas the research and development department remain in Tinglev. Production takes place in three modern facilities in China and in Chile.

In 1993 Maersk Mc-Kinney Moller steps down as CEO of Maersk and was succeeded by Jess Søderberg, who headed the company from 1993 to 2007.

In the same year Maersk acquired EACBen Container Line which made Maersk the largest container Shipping company in the world.

In 1999 SeaLand and Safmarine was acquired. Both companies continued operating under their original names.

In 2001 APM Terminals was founded. Since entering the container business, Maersk Line had invested in terminal facilities around the world. The portfolio of terminals was significantly increased with the acquisition of SeaLand in 1999 and it was decided to establish APM Terminals as an independent business unit providing port and inland infrastructure services. APM Terminals currently operates 73 ports and terminals in 36 countries and continues to expand. In 2005 Maersk acquired P&O Nedlloyd. The British P&O and the Dutch Nedlloyd container shipping companies were merged into P&O Nedlloyd in 1995. In 2005, the constellation was acquired by A.P. Moller Maersk. During the integration process, the Maersk SeaLand brand was changed back to Maersk Line (as before 2000). The integration of one large, global organization into another large, global organization proved difficult, but eventually provided Maersk Line with a scale that would not have been possible through organic growth.

In 2012 Maersk Mc-Kinney Moller passed away at the age of 98. At this point Mr Moller was still active chairman of the A.P. Moller foundation, but after his dead his youngest daughter Ane Mærk Mc-Kinney Uggla took over his position.

In 2015, the official opening of APM Terminals most technologically advanced and sustainable container terminal Maasvlakte II took place. The Maasvlakte II runs entirely on power generated by wind turbines and is the world's most automated container terminal to date.

In 2016, it was announced that the previous conglomerate business structure of A.P. Moller – Maersk was to be reorganized into two separate divisions – an integrated Transport & Logistics division containing Maersk Line, APM Terminals, DAMCO, Svitzer and Maersk Container Industry and an Energy division.

The main growth focus of A.P. Moller Maersk going forward would be on the transport and logistics services. The oil and oil related businesses were to be separated from A.P. Moller Maersk, either individually or in combination. In 2017 the Oil business were sold to Total.

In February 2018 Maersk acquired Hamburg Süd, making Maersk line the largest shipping company in the world and thereby completing the mission set by Mr. Arnold Peter Moller and Captain Peter Maersk Moller in 1928 when Maersk line were established.

Introduction – Three waves of IT-driven competition

Today it is evident that technology is revolutionizing products and services. Historically products and services was composed solely of mechanical and electrical parts, today products and services can be seen shaped as complex systems that combine hardware, sensors, data storage, microprocessors, software and- connectivity in numerous ways (Porter, 2014). Such products and services are coined as *"smart, connected products"* by Michael porter, and these products have been made possible by enhancements in processing power and device miniaturization. Moreover, these products and services are enabled by the network benefits of ubiquitous wireless connectivity – unleashing a new era of technology driven competition. Connected products and services is at an exponential pace creating opportunities for new functionality, reliability, greater product utilization – and capabilities that surpasses traditional product boundaries. As products and services are changing in nature, organizations are forced to rethink and retool nearly everything, around – and how they conduct their business processes both externally and internally (Porter, 2014). The new types of products and services are altering industry structures and forcing changes towards the nature of coemption, exposing organizations to new types of competitive threats and opportunities. Industry boundaries are being reshaped and many new industries arise, due to the very same opportunities. As Michael Porter states in the Harvard Business Review of 2014, many companies are today forced to ask themselves; *"what business am I in?"*, namely due to the emerging technologies around smart connected products and services. This is also a question raised by Maersk; *'are we a container shipping company, or are we a world-class IT organization that happens to own a lot of vessels and metal boxes'* (Adam Banks, 2018).

The phrase "internet of things" (IoT) has the past decade been one of the most frequent used buzz words within the IT field. A term arisen to reflect the increasing number of smart, connected products and to highlight and merge the new opportunities they can - and ultimately will represent. However, this phrase has in general not been considered helpful in terms of understanding the phenomenon and/or its implications. The phenomenon will be further elaborated upon, after briefly understanding the first two waves of IT-driven competition and the evolvement of the internet;

The first wave of IT-driven competition, before the arrival of modern information technologies, products were mechanical and activities across the value chain were conducted using manual paper processes and was dependent on verbal communication. According to Porter the first wave of IT occurred during the 1960s and 1970s, individual activities got automated in the value chain, from order processing and bill paying to manufacturing resource planning enabling a transparency in the production, which was previously unseen. Productivity increase was driven as the newly generated data could be captured and analyzed for each activity. Porter states how this led to standardization of processes across companies and increased the focus from organizations on how to leverage value from IT's operational benefits.

The second wave of IT-driven competition, in order to understand how IT drove the second wave of competition, it is vital to understand how the world wide web, evolved to enable the second wave of IT product/service driven competition;

Web 1.0 is the first iteration of the internet as we know it (1993 – 2006). The web 1.0 is considered as a read-only era of the world wide web, only consisting of flat or static data. The web 1.0 did not allow for interaction between the IT product/service and the web user. The world wide web was simply considered a portal of information, wherein users passively receive information without having the opportunity to interact in the content on a given webservice. Web 2.0 is the second iteration of the internet as we know it (2006 – 2016). The web 2.0 is considered as the read/write era of the world wide web, consisting of dynamic interactive user generated data, allowing users directly to interact with the web product/service. Moreover, the uniqueness about the web 2.0 was that users of a given system could directly interact with the system and communicate and knowledge share across geographical boundaries – inexpensively and with ubiquitous connectivity. This unleashed the second wave of IT-driven transformation. Organizations got enabled to coordinate and integrate across individual activities; internally, with external suppliers, channels and customers (Porter, 2014). Organizations was furthermore enabled to integrate themselves in global distributed supply chains, which was disrupting the shipping industry;

… A new level of coordination across Vessel Shipments, Intermodal transportation, communication and alignment with customers and third parties had risen.

During the first two waves of IT-driven competition there was an increase seen in terms of productivity gains and growth across the economy. While the value chain was transformed, however, products and services themselves were largely unaffected. This leads us to the third wave of IT-driven competition.

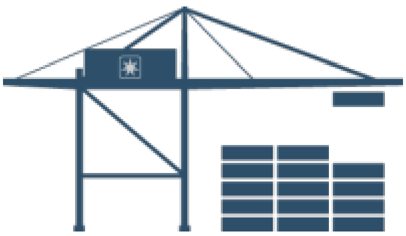
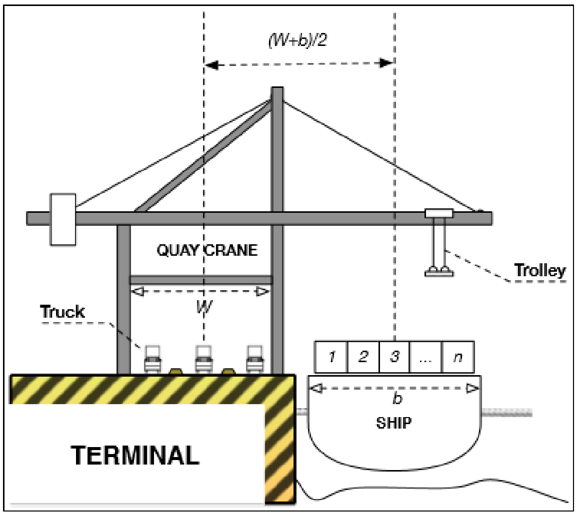
The third wave of IT-driven competition, is what is coined as the era of Internet of Things (IoT). The internet is in its nature a simple processing mechanism of information. This nature of the internet remains the same within the third wave, however what is the changing is the nature of what is being internet-enabled. In the third wave, IT will become an integrated part of a given product or service. This is empowered through; embedded sensor data, GPS, processors, software and internet-enabled physical products (e.g. a container with an installed computer, with internet). The connected products can be coupled to cloud-based data repositories, wherein the data being generated is stored for the given product or service entity. In the repositories data is being stored and analyzed in order to capture patterns to drive improvements in product or service functionality and performance. A vast amount of data on new product/service-usage is enabling organizational improvements, which will be uncovered in later sections of this thesis. According to Porter;

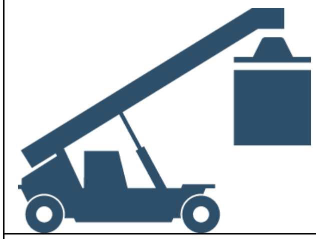
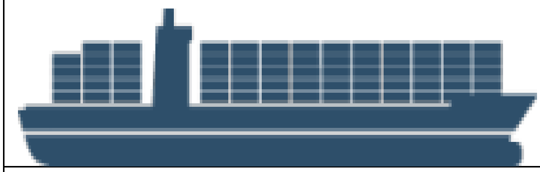
"Another leap in productivity in the economy will be unleashed by these new and better products. In addition, producing them will reshape the value chain yet again, by changing product design, marketing, manufacturing, and after-sale service and by creating the need for new activities such as product data analytics and security. This will drive yet another wave of value-chain-based productivity improvement. The third wave of IT-driven transformation thus has the potential to be the biggest yet, triggering even more innovation, productivity gains, and economic growth than the previous two" (Porter, 2014)

Throughout this thesis we will validate Porter's assumption, and hopefully uncover how productivity and service improvement for Maersk T&L will be achieved through an internet-enabled end to end process of the operational shipping cycle, with an emphasized focus upon the terminal operations.

Glossary / Terminology

Below table outlines the terminologies that we use to explain the entities that constitute the terminal operations:

Term	**Explanation**
Quay Crane 	A Quay Crane is a crane that is stationary at the edge of the harbor. The purpose of this crane is to unload and load containers from the container ship onto a truck that can park directly under the crane as shown on the illustration below:  As we can see each Quay crane have room for 3 trucks in waiting position under the crane. As the crane is stationary they have a limited reach from left to right.

Shuttle Carriers 	The main task for the Shuttle Carriers in the terminal is to move the containers from the Quay Crane and into the container yard, where the container will be placed by the Reach Stacker Crane. A loaded Shuttle Carrier can drive with 15 km/h.
Reach Stacker Crane 	A Reach Stacker Crane is a crane that can drive like a truck with speeds up to 25 km/h. It also has a lifting arm that can lift containers 18 meters up in the air. The use of the Reach Stacker in the terminal is to take the container off the Shuttle Carrier and place it in the terminal yard.
Container Vessel 	The Container Vessel comes in many different sizes where the smallest is the A class and the biggest is the Triple E Depending on the size it containership must chose the correct port. The containership is transporting the containers from one terminal to another.
Pre-Berth	Pre-berth is the event when a ship is 2 hours away from docking at the designated port. The event is basically the captain of the ship pressing a bottom that send a message to the Terminal that it will arrive in 2 hours.
Berth	Berth is an event where a signal is sent to the Terminal that now the ship is docking at the chosen location.
RCM	RCM stands for Reefer Container Management. A Reefer Container is a refrigerated container where you can choose a specific temperature you want inside the container. This kind of containers are mostly used for Food products. The Reefer containers comes in two different sizes: 20 Foot Reefer and 40 Foot Reefer. And is already GPS enabled. 
DCM	DCM is an abbreviation for Dry Container Management. Dry containers are normal containers that comes in 20 feet and 40 feet size. DCs are currently **not** GPS enabled.

GCSS	Global Customer Service System is the booking system of containers.
GSIS	Global Schedule Information System this system includes data about estimates and actuals of when ships and containers will arrive.
LastFreeDay	Is the amount of free dates that the customer buys with regards to his/her booking and based on this data object we can calculate "Expected Pickup date"

Table 1. *Glossary*

Methodology

The research framework applied for this Thesis is the research onion, this was developed by Saunders et al. (2007). The research onion illustrates each of the stages that must be covered as part of developing a research strategy. It has been widely used throughout the course of our under-graduate and graduate engagements, and has proven as a strong framework and guiding principle to ensure that adequate and detailed research is conducted. As seen from the outside, each layer of the onion describes a more detailed stage of the research process (Saunders et al., 2007). The research onion is designed so that it provides an efficient progression, which in turn a research methodology can be designed upon. It is widely recognized for its usability and adaptability for most types of research methodologies and further the framework can be used in a variety of contexts (Bryman, 2012).

The research onion moves through five stages, in the five stages the research is brought through an effective methodology for setting a clear and thorough research strategy. Each stage is as briefly described below and in the following section each of the stages will be thoroughly described and related to the research methodology applied in this thesis. *First*, the research philosophy is being defined. The research philosophy sets a foundation and creates the starting point for the research approach, which is the *second* step adopted. *Third* step of the research onion the research strategy is being defined. The *fourth* layer identifies the time horizon in which the research has been conducted. Finally, the *fifth* step represent the activities conducted around data collection – whether being; Primary data, secondary data, observations, etc. The benefits achieved through the appliance of the research onion are thus a process that covers the end to end process of collecting and research data.

Research philosophy

This thesis is an empirical study on how Maersk T&L currently conduct their operational shipping procedures related to unload of containers from vessels. The research philosophy helps us identify the beliefs and the nature of the reality we are striving to investigate and research (Bryman, 2012). The research philosophy sets the underlying definition of how knowledge is to be perceived. The assumptions defined and created in a research philosophy, provides a justification for how the research will be conducted (Flick, 2011). At the basis research philosophies differ between two approaches interpretivism and positivism. This paper takes a qualitative interpretivist approach towards data gathering and research conducted on the same. The interpretivist approach believes the nature of reality is socially constructed and that individuals may perceive X-situation different from one another – dependent on the individuals own view of the world and their constructed reality (Saunders, et al 2012). Interpretivism allows for a subjective approach and is more focused on the micro level and granularity of research, as seen in contrast to positivism – which concerns with macro level quantitative research settings. Furthermore, one of the cornerstones in an interpretivism research philosophy is that the collection of information, data and knowledge is obtained through; semi-structured interviews, participant observation and ethnography. As both of us have been working in Maersk T&L for the past four years, this approach was a natural fit for this research.

Research approach

We consider our research approach as being both inductive and deductive throughout the thesis, and especially throughout the preliminary research. In our research, we sought to achieve a better understanding of the operational shipping procedures and the legacy software system landscape. Ultimately to identify; how these could interplay to obtain unseen values and benefits from an organizational perspective, driving competitive excellence through IT. Both the inductive and deductive is supported by collection of data through; interviews, observations, and secondary data. The inductive approach is considered as a bottom-up approach for research. It is starting the research with observations, then attempting to achieve sense-making of these observations and to establish a pattern. To conclude on the observed patterns, theory is being applied to get a more granular understanding of what it is that has been observed. As mentioned above the focus during our observations was to understand the actors throughout the unloading procedures of containers, as well as the current legacy as-is software landscape. By observing and understanding these we have gained a foundational knowledge to place our proposed system's building blocks upon. The data collected from our interviews and the understanding obtained through observations is applied in the chosen theoretical frameworks, to be able to understand the posed research question adequately.

As mentioned above, we would also argue that our research approach is deductive. The deductive approach is concerned with the fact that a researcher holds conclusions and assumptions, as well as; having theories in scope prior to starting the research. Meaning, that the research is not set in place to formulate a new theory based on the research (Wilson, 2013). Prior to our research we both held assumptions and conclusions, furthermore we had decided that the technical cornerstone of theoretical framework would be the EPCGlobal Future Architecture Model. However, it should be noted that none of the formal or informal interviews conducted have been forced to answer questions directly related to this technical framework.

Interviews have been open in nature, and we have allowed the participant to evolve and elaborate his thoughts and views as we moved forward. What also characterizes the deductive approach is that a hypothesis is developed upon an existing theory. The research approach is then in turn formulated in order to validate or reject the posed hypothesis. In this setting, one may consider the research question as the overarching hypothesis, that we seek to answer through the paper.

Research Strategy

The research strategy describes how a researcher intend to carry out the work related to the research. As Saunders states; the research strategy is defined as the method in which, and how the researcher will go about answering his/her research question. He further describes how it is the methodological link between philosophy and subsequent choice of methods to collect and analyze data (Saunders et al., 2012). The research strategy of this thesis is a qualitative case study, this is based on the argument that we are conducting a qualitative research and interpreting a single research setting. Furthermore, to support the argument; we strive to explore and understand phenomena within a given context, which in this specific case is the IT driven value derived from the potential implementation of digitization in physical operational procedures (IoT). This case study enabled us in greater insights of the research setting and the relevant operational procedures as well as legacy software landscape. We achieved to generate answers to “why”, “what” and “how” by following techniques such as interviews, observations and documentation (Saunders et. al., 2012). In addition to these techniques, one must note again that it is inevitable that we have been influenced by a sense of ethnography. We have both been closely observing, examining and been an integral part of the Maersk T&L organization. However, the ethnography is mostly related to the observance around the software legacy systems and the automation teams. Unfortunately, we have not been able to visit the terminals physically and hence we will not be able to argue that we have achieved a sense of ethnography within this area.

Time Horizon

The time horizon is an important aspect of the overall approach to the research as it determines the period in which the research is based upon either; cross-sectional or a longitudinal study. The time horizon of this research setting is cross-sectional, or a snapshot in time. This is since the data collection is constrained to set period and not a repetitive exercise following the as-is state of Maersk T&L over a longer period. Our research strived to understand how Maersk T&L currently conduct their unloading procedures, in order to identify and understand how this can be done more efficiently. Note, that we allowed our observations and interviews to evolve and emerge as we proceeded. Hence interviewees did express prior experiences from the past, these expressions have been considered but was not part of the initial intention of the research time horizon.

Research Techniques and Procedures

As mentioned in the above section, the data collection techniques we have used have been a mix of numerous approaches in order to acquire an in-depth understand of the research setting. Primary data have been acquired mainly through non-standardized interviews with non-leading open-ended adaptive questions and strived to gain a naturalistic interaction with the interviewees. Some questions have been guiding towards our specific area of interest. Moreover, we tried to establish an open conversation during the interviews; meaning that interviewees were enabled and free to express their personal thoughts and perceptions. This in turn allowed us to ask spontaneous questions as we progressed through the interviews we conducted. The few guiding questions that we did ask in accordance to our theoretical framework, enabled us to establish insights and understanding of how the current operational activities related to container unloading was conducted. And conversations with technical personnel helped us understand how the current state of the software system landscape, which in turn enabled us to identify and evaluate the building blocks for the proposed software robotics. In addition to primary data, we have collected secondary data from internal technical documents to understand both the software landscape and the physical hardware present in the terminals. We have also reviewed and analyzed design documents from both APMT and ML, in order for us to get an understanding of the digital transformation both entities are going through. This enables us to establish a sense of how these two entities in a joint effort may achieve benefits from combining their transformation initiatives. Lastly, in terms of secondary data we have acquired knowledge from different Maritime magazines to get a thorough understanding of the current market state. Our ethical standards have been apparent and clear for participants during our research. In all conducted interviews, we have made it explicit and expressed our intentions and the process. This involved informing the interviewees about their rights to not answer questions that they did not desire to answer, as well as clearly expressing the **confidentiality** that this thesis is bound by. Ahead of interviews and observations we have requested whether notes and audio recordings was allowed or prohibited. To summarize, we are confident that the research strategy followed throughout this process have been sufficient and achieved the expected outcome in terms of establishing a strong foundational knowledge, to base our findings and discussions in.

Limitations of research

As a final note, or disclaimer, to our methodological section we would like to shed light upon the limitations that we have faced throughout the process of research. The interpretive approach taken concerns with us making sense and understanding of the collected data and observations. As we have both been employed by Maersk Line through the past 4 years, we may have acted subjectively and biased with regards to our data gathering. This may be considered as a limitation as our rationale have been bounded by the social reality that we have constructed in working as an integral part of the organization over a longer duration of time

(Bounded Rationality). Furthermore, we had initially planned to have on-site visits in the APMT Terminals in (1) Maasvlakte to see the cutting-edge technologies that is currently being deployed in their infrastructure. Moreover, we had had also planned to visit (2) Aarhus terminal, as the proposal through this thesis takes its basis in Aarhus Havn's terminal. Both on-site visits did not happen due to time constraints and availability of the right resources to be interviewed during the onsite visits. Hence, we identified it would be sufficient and adequate to obtain documentation from these resources instead of spending a full day at the operational site. We are confident that the research obtained from this is sufficient, however we are certain that our overall understanding of operational procedures would have been enhanced further by having 'eyes-on' experience from both terminals. Other limitations that we have faced in the research is company sensitive data like; costs associated to physical quay crane operation (people), digitization costs (of terminal hardware), costs associated to software development and integration to physical assets in terminals. This have made it difficult to form a granular cost-benefit analysis as our costs are mainly bound based on assumptions/estimates. However, we are achieving to show-case the method in which we would have done the actual cost-benefit (if we had the actual costs), hence we are satisfied with the achieved result. The final limitation that we experienced throughout the writing of this thesis was our ability to obtain data on how the proposed solution could be rolled out. Moreover, we did not achieve to get an understanding of the considerations the managerial layer of both APMT and ML would take in an implementation scenario of robotics and IoT.

Problem Statements – Research Question

In the above section of the company introduction we understood that Maersk T&L have a unique position in terms of owned property and infrastructure, enabling them in full control of the end to end shipping cycle. This allows Maersk T&L to aspire towards becoming the global integrator for all container transport; whether it being on major shipping vessels, barge ships, inland trucking transport or rail transportation. This paper seeks to identify potential synergies that may exist and can be leveraged upon between ML and APMT. The core of the synergies that we strive to identify lies within the technological area, both in terms of digitization of physical hardware in the terminals (IoT) and how this potentially could interplay with the existing legacy system landscape in Maersk Line. The solution that we are proposing will in detail be explained in a later section of this paper, prior to doing that we will identify the problem statements that we seek to resolve with the implementation of our proposed solution. But establish a contextual understanding for the reader the proposed solution encapsulates a fully automated container lifecycle from 2-hours pre-berth until the container have been placed in container yards awaiting customer pick-up.

Communication gaps

Current state in terminal ports make the operational stakeholders reliant on traditional radio and radar communication between captains, terminal operators, tugboats and other operational participants. Key decision-making is made through these traditional technologies (radio and radar communication), forcing complexities related to coordination between the different stakeholders in the container lifecycle from; pre-berth to container placement in container yards. As the communication required between the stakeholders in the lifecycle is vast and happening between numerous participants, it makes it extremely difficult to abide to the critical path for the operational procedures (Alexandru Duca, 2018). Moreover, since the coordination between teams and operators are done manually the process is error prone, disabling the operation to achieve efficient performance. By being disabled in following the critical path, there is a direct impact towards carrier liners and terminal operation. Carriers, are forced to berth for longer durations, instead of being in-voyage towards their next location. And with regards to terminal operation the terminal is limited in berthing additional vessels (as there is a limitation to number of quay cranes), causing a direct impact on both liner – and terminal business. Ultimately causing bottom-line impact for both ML and AMPT.

Bix boxes, big risk

ICHCA International statistics on maritime inland accidents shows (as illustrated in chart) that 41% of all accidents, within shipping operations, are related to the activities happening at the quayside. Quayside operations compromise berthing and mooring operations, loading and discharge of containers, lashing and unlashing operations of cargo at the quayside. With the proposed solution comes a fully automated container unload procedure, reducing the amount of human interaction and thereby reducing the risks involved for the operators at the quay side. The risks involved in working within the Maersk group (and the shipping industry in general) is also considered a problem statement, seen from a managerial perspective. Shipping operations are error prone and management strives to accommodate a safe working environment for all its employees.

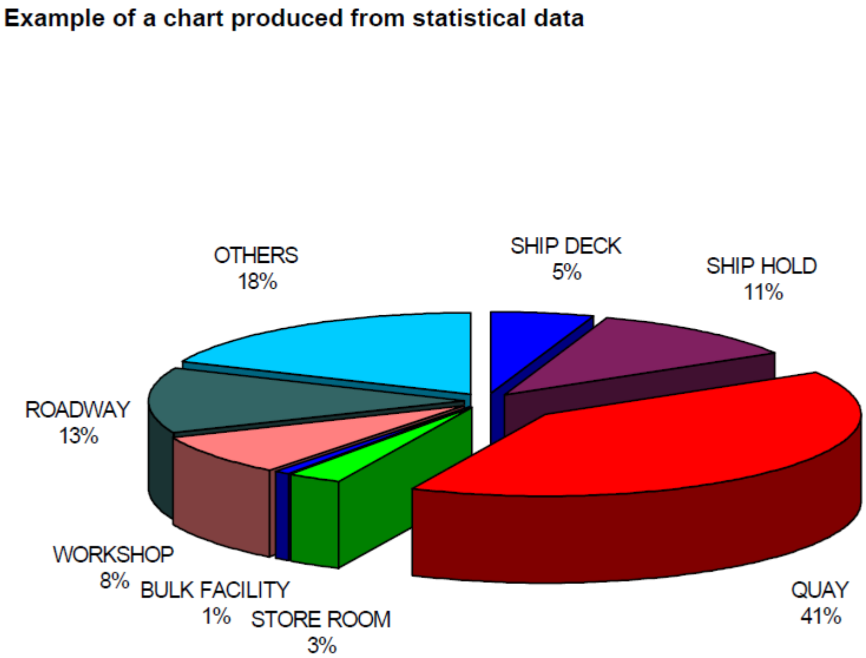


Figure 1. *Accident Chart*

Continuous learning

There is little digitization of physical assets in APMT's terminal ports, this means that the amount of operational data generation from day-to-day activities is scarce. This causes a fundamental issue with driving improvements from lessons learned, as there in most cases are no clear visibility of which pitfalls are causing a given terminal's good or bad performance. Examples could be; variance reduction, quay crane cycle times or increased safety. Hence it is difficult to draw best-practice outcomes that can be implemented globally across, as there simply doesn't exist the required data to support such endeavors. Digitization of physical assets will not automatically resolve these constraints however it will enable both ML and APMT to make informed decision-making on how to improve, and thereby drive a best-practice standardization globally across terminals.

Operator Variance

In continuation of above mentioned enablement of continuous learning, another factor that would be eliminated with the introduction of a fully automated robotic driven terminal is the inconsistencies and variances that exist between different operators. Whether being; QC operator, Truck operator or Reach stacker operator (Alexandru Duca, 2018). Currently there are high variances between each operator and as not much data is being generated it is difficult for management to identify, where and when additional training is required.

Container unload scheduling

Quay cranes (QC) perform the unload activities of containers from vessels, where after the QC places the container on a shuttle carrier. At the current state of operation, there is an allocated scheduling team who manually schedules the order in which the containers are being unloaded in. However, trained this specific team of schedulers are, it is a complex and difficult task to define the most efficient unload pattern for a vessel containing more than e.g. 18.000 containers. This means that in the operations surrounding unload procedures personnel are not always enabling the operation to follow the critical path for efficiency. This thesis will only cover the problem statements that relates to unload of containers, meaning the import cycle of the shipping cycle. However, it has to be noted by the reader that the resolution to the unload scheduling, will root to a proper load of containers at the export side of the shipping cycle. To elaborate on this; If container (a) and container (b) is being loaded on a vessel for export from Hong Kong. Container (a) is being exported to Felixstowe, whereas container (b) is exported to Aarhus, then it is equally important in export scenarios that container (a) is being on-loaded on top of container (b), instead of container (b) is being loaded on top of (A). This ensures the least container re-scheduling/re-ordering during the vessels voyage. In the given example Felixstowe is the first terminal, subsequently followed by Aarhus.

Quay crane and truck alignment

When the QC unload a container on a truck it is difficult to achieve alignment between the QC and the Shuttle Carrier. This causes a direct impact on the efficiency of the QCs and how many containers the terminal is able to process. Furthermore, there are in cases 'conemen' assigned to assist in the alignment of the QC and truck, conemen are operating on the ground under the QC and container which is causing a large risk with regards to safety.

Container Yard optimization

Similar to the waste related to *container unload scheduling* there are considerable amounts of waste related to the procedures that happens after a container have been unloaded from the QC. In most instances, the container is being unloaded directly to an intermodal carrier's truck and driven towards the customers store door. But in those instances where there are no scheduled pick up on the day of arrival, the container will be placed in a container yard until the customer have scheduled to pick it up. This means that the container will be placed in the container yard based on the amounts of *Last Free Days* the customer has requested/purchased. Last free days indicates how many days the customer may wait to pick a container, without being charged additional demurrage fees. Hence there is a big variance in the amount of days a given container is placed in yards. The variance of free days causes considerable coordination activities of the container placements in the container yards. Again, this can be considered as a problem due to the man-made decision making that must be done to identify the most logical and efficient order to place the containers in. This means that the current state of container yard operations there is a lot of forth and back movement of each container, because containers are not placed in the most efficient order when they first arrive at the container yard.

Based on the above seven problem statements we have now understood the primary issues that exists in APMT and ML, we consider these to be blockers for APMT and ML preventing them from reaching operational excellence. Our research throughout this thesis will be targeted towards identifying possibilities and ultimately formulate a solution that would mitigate the current risks and issues at hand. With inspiration from two courses taken through this Master of Science program; Robot Armada and Internet of Things we decided that we would aspire to muck an architectural solution combining robotics with IoT enabled digitized physical hardware. *Creating a shipping infrastructure in accordance to the third wave of IT-driven competitiveness.*

This leads us to the overarching research question that we aim to answer throughout this thesis, related to APMT and ML:

How can AP Moller Terminals and Maersk Line derive value from software robotics and a digitized terminal infrastructure in Aarhus Havn?

In order for us to adequately answer above research question we intend to structure the thesis in the following manner. *First,* we will thoroughly describe the theories that we will use to answer the research question in the theoretical framework section. Note that we have selectively used concepts from each of the theories that we have found fit for this thesis, meaning that some frameworks may appear limited in nature – this is done to ensure relevance for the analysis and for the reader. *Second,* we will describe and present the overall solution that we are proposing. The high-level solution will be presented prior to the analysis, as we trust that it is vital for the reader to understand the solution that we base our business -and technical analysis upon. *Third,* we will analyze the solution first from a business point of view outlining the business case and understanding the cost / benefit from the solution. The business section will be finalized with a

Business Canvas Model, this is to establish a tangible 'one-pager' that can be used as an easy summary to understand the proposed solution in a holistic manner. The business analysis will be followed by a technical analysis, herein we will apply the theories from the IoT domain as well as theories advised by Kim Normann. The MUST method will be used as a tool to identify and assure that business requirements are understood according to the actual requirements, driving participatory design. The EPCglobal framework will be applied to get a thorough understanding of the architectural building blocks of an IoT solution. Additionally, we will take an in-depth look at the robotic software components that will work as an integral part with the IoT components. The Holistic Model is being applied to understand the content providers and the components that drives benefits of the IoT/Robotic Software solution. In the *fourth* section of this paper we will discuss the findings that we have obtained through our analysis. In continuation of the discussion. The *fifth* section of this paper will reflect upon the learnings that we have achieved, our learnings will be baselined against the learning objectives of the Robotics and IoT course taken through this course. Furthermore, we strive to reflect upon the overall learnings that we have achieved by being enrolled to this program. *Sixth* and final, we will conclude upon the findings of this thesis.

Theoretical Framework

As previously mentioned the framework throughout this thesis is split in two different focus areas. The first section will cover the business benefits driven by software robotics and IOT capabilities. Whereas the second part of the paper's analysis will uncover the technical components required in order to enable the proposed the solution.

Business Case

We have decided to use a Business case because the business case brings together the benefits, disadvantages, costs, and risks of the current situation and future vision so that executive management can decide if the project should proceed. When we will be doing the Business case in our analysis we will assess following aspects of the project: *business problem, opportunities, benefits, risks, cost including investment appraisal, technical solutions, timescale and impact on operations to deliver the project outcomes.* Assessing these seven aspects of the project will teach us about the current issues and the benefits of the future vision.

The seven above mentioned aspects are in below table depicted and described, to clarify for the reader what our focus will be at each of these stages in the business case analysis.

Finance The first section is the **Finance section**, in which we will do our Financial appraisal and sensitivity analysis of the project.	
Financial Appraisal	The **Financial appraisal** are used to identify the financial implications of the project, allowing APMT and ML to compare costs with forecasted benefits of the project, ensure that the project is affordable, ensure that we get value for money and lastly to predict the cashflow.
Sensitivity Analysis	**The sensitivity analysis** is done in order to look how much the project can change and still materialize on the investment.
Project Definition Next section in the business case in the **Project Definition**. The Project Definition is the largest part of the business case and is for the stakeholders, sponsors and project team. When done correctly this section should answer most of the why, what and how questions about the project.	

Background information	This part will not be covered in the business case, even though it is part of the framework, as this is already covered this in; introduction and problem statement section.
Business Objective	Next, we will describe the **Business Objective** for the project to explain Why are we doing this project. To describe the business objective, we need to answer: • What is our goal? • How will the project support the business strategy?
Benefits and Limitations	The third area in this section is the **benefits and limitations** where we will describe the financial and non-financial benefits of the project and how it will benefit the organizations. In this area, we also talk about the limitations of the project and the limitations of the benefits.
Option Identification and Selection	Next up is the **Option Identification and Selection**. This area is to Identify the potential solutions to the problem and describe them in sufficient detail for the reader to understand. For instance, if the business case and proposed solution makes use of technology, make sure to explain how the technology is used and define the terms used in a glossary. Since most problems have multiple solutions an option appraisal is often needed. This will explore the potential solutions and recommend the best option.
Scope, Impact, and Interdependencies	After looking at the different options we will look at; **Scope, Impact, and Interdependencies**. We use the Scope, Impact and Interdependencies to describes the work needed to deliver the business objective and identifies those business functions affected by the project. Moreover, the scope, impact, and interdependencies section should state the project's scope and boundaries. It describes what is included and what is excluded plus the key interdependencies with other projects. It is important for the business case to consider the failure of other interrelated projects and show how such dependencies make impact benefits.
Outline Plan	**Outline Plan** is the next area we will look at and it is about summarizing all the main activities of the project in regard to the timeline of the project. The questions we are trying to answer in this area is: • What is required? • How is it done? • When will things happen?

Market Assessment	The market assessment should show a complete understanding of the marketplace in which your business operates. We will assess the market by doing a **PESTLE** — *political, economical, sociological, technological, legal, and environmental* — analysis.
Risk Assessment	The risk assessment summarizes the significant risks and opportunities and how they are managed. The risks included should cover those that could arise from you project or the organization's ability to deliver change. This section answers the following questions: • What risks are involved? • What are the consequences of a risk happening? • What opportunities may emerge?
Project Approach	The project approach section describes which approach we will take to deliver the project, both in terms of the IoT components and the Robotic Software.

Table 2. *Business Case Framework*

Cost Benefit Analysis

To summarize on the Business Case and to show a clear picture of the value of doing this project we have chosen to do Cost/Benefit analysis. The cost/benefit will show the costs and benefits that we uncovered during the analysis and writing of the business case. The cost/benefit analysis is a strong tool that gives a clear illustration on when the organizations may expect a return of their investment.

Business Model Canvas

For many years, most firms were focused on industry (Porter 1980) and resources (Barney et al. 2001, Wernerfelt 1984). Business model Canvas has now taken over as a replacement of the traditional unit of analysis due the change in business environment. Back in 1998 Sampler called for an alternative to the traditional value chain. The increased competitive environment driven by dramatic technological progress, a series of new types of businesses. Even today the business conditions in the market is largely influenced by technological development, service orientation and the digitalization of corporations' ecosystems which blurs the lines between individual enterprises. This calls for analytic models that are holistic and can comprehend various aspects of the business. The analytical model should be able to entail competitiveness of a firm by offering a logistical and consistent approach to the design and execution of the business. This lead to the first Business Model Canvas to be developed. Its popularity quickly grew with the emergence of electronic commerce and the dot.com phase. This increase in popularity can be explained by shortcomings in existing frameworks and theories to address all aspects of the novel possibilities defying conventional ways of doing business (Chesbrough and Rosenbloom 2002).

However, the business model was new in the market, the underlaying theories were not new. Aspects defining the business model could already be found in Drucker (1954) and in concepts of strategic management (see e.g. Hedman and Kalling 2003, Morris et al. 2005).

No matter the business, its activities can be broken down into its core elements which are; *Value proposition(product), Infrastructure management, Customers* and *Financial aspects*. This means that all businesses have an underlying business model even if it is not explicitly presented. Even though the term "Business Model" is often used both in research and practice, there are missing a common definition (Morris et al. 2005). One of the most cited definitions of the term can be found in Timmers (1998). He defines a business model as "an architecture of the products, services and information flows […]". In this architecture, the main questions you want to answer in your business model are:

What is our business? Who is the customer? What is value to the customer? What will our business be? (E. Bucherer, D. Uckelmann)

The answers to these questions are anchored within different parts of the business model canvas as illustrated below, each point will be seen in light of the proposed solution for APMT and ML.

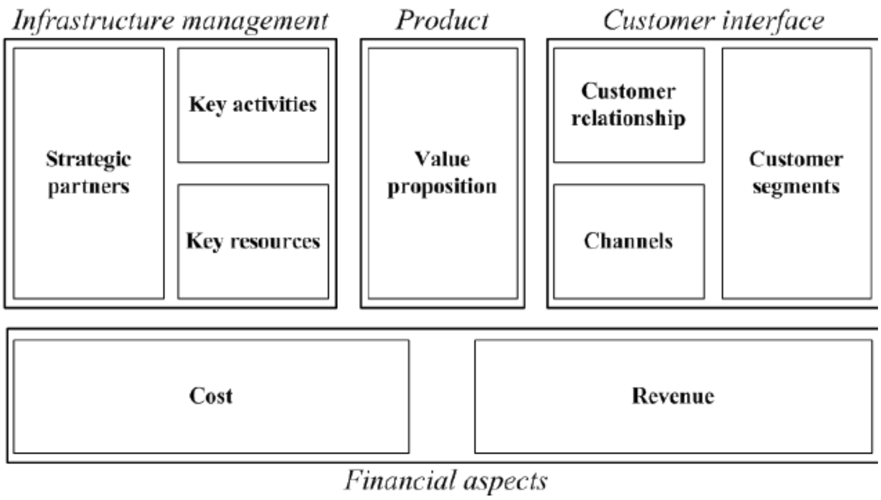


Figure 2. *Business Canvas Model Framework – Core Elements*

Holistic Model of Internet of Things

The Holistic Model is a framework that was presented during Internet of Things course. In the original framework, the model also accounts for public institutions and private people, however this have been ruled out for this thesis, due to lack of relevance. The Holistic Model is used to illustrate and depict how an organization may function as a content provider. Based on the usage and content provided, by organizations, data is being generated. This data is in turn used to enable IoT components of the given business setting or procedure that has been IoT enabled.

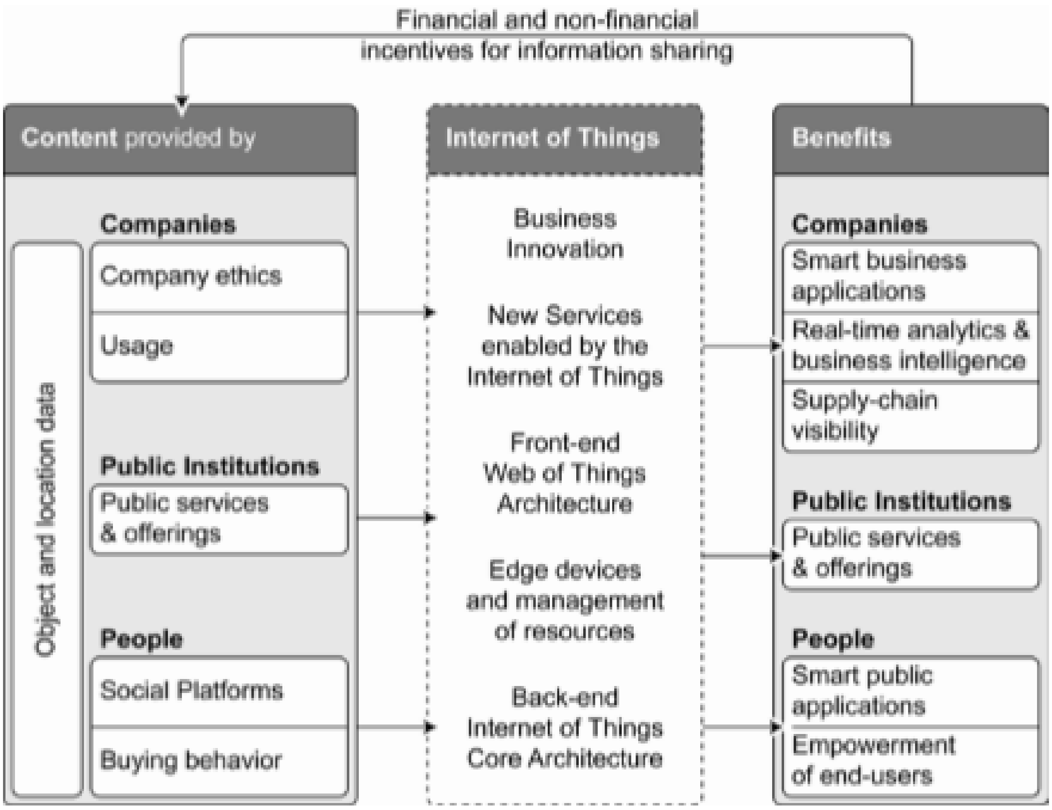


Figure 3. *Holistic Model Framework*

The Holistic Model divide the IoT capability into five foundational traits for value generation and benefits. Each part of the proposed solution will be segmented and evaluated in terms of IoT trait and the benefits that it is being derived from the same.

EPCglobal Future Architecture Model

The EPCglobal Future Architecture Model was also presented and studied during the IoT course. EPCglobal is a global association that is leading in development of industry standards, driven through norms and standardization of Electronic Product Codes (EPC). EPCglobal's goal is to establish a network of EPCs, which in turn should be used as a global specification, to drive international standards. To elaborate; this means that EPCglobal strives to establish unique identifying schemas that can be used across industries, the standardized and global aspect of their unique identifying schemas makes it easy to subscribe to as an organization. Note that the EPC is not a single identifier scheme but it is serving multiple industries, a relevant identifier scheme for the setting we are assessing is that there exist a EPC for Serial Shipping Container Codes. This means that any container operated in an APMT terminal that are not from a ML brand will be identified, as it globally identifiable due to the tagged EPC. The Future Architecture Model will be used in this thesis as a generic foundational framework to understand the core building blocks in an IoT solution.

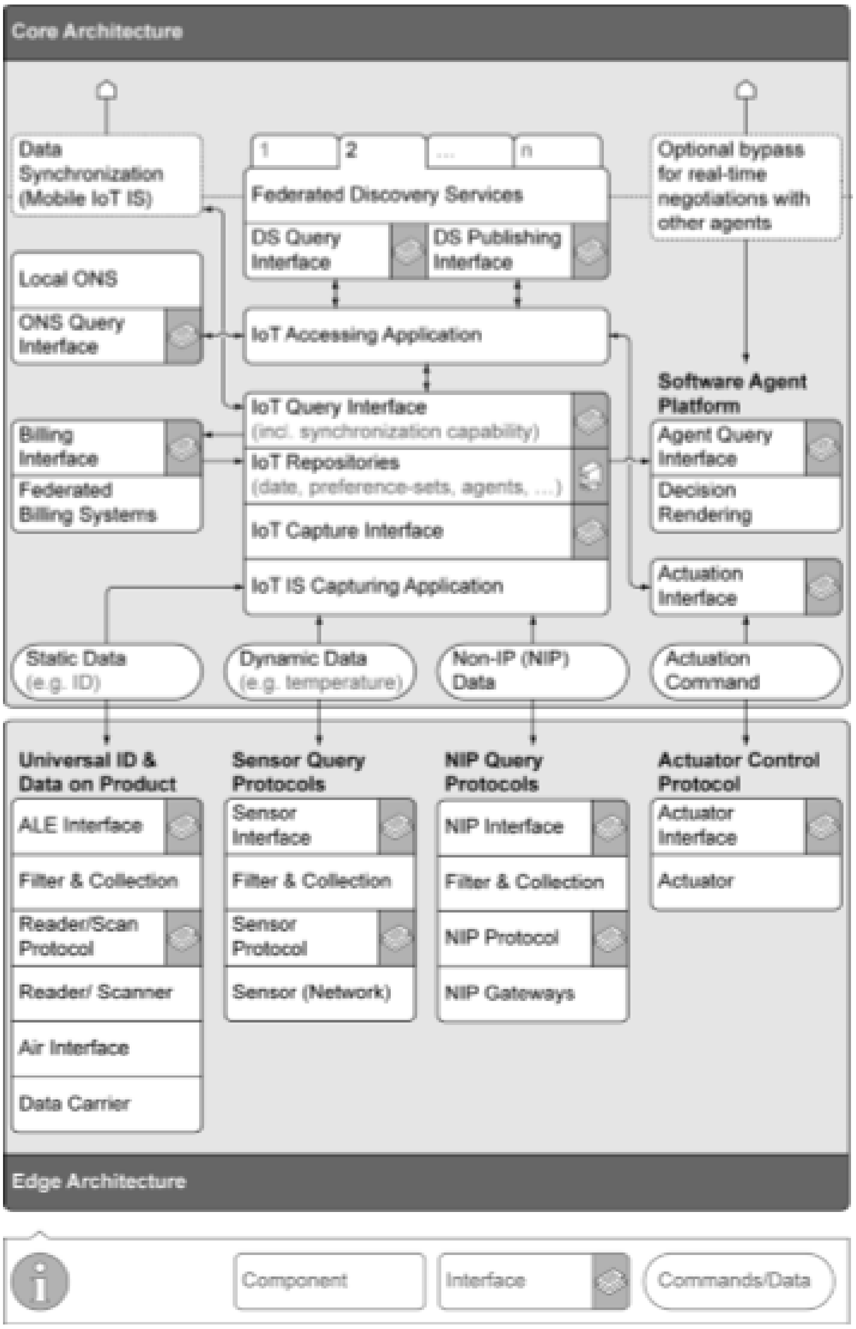
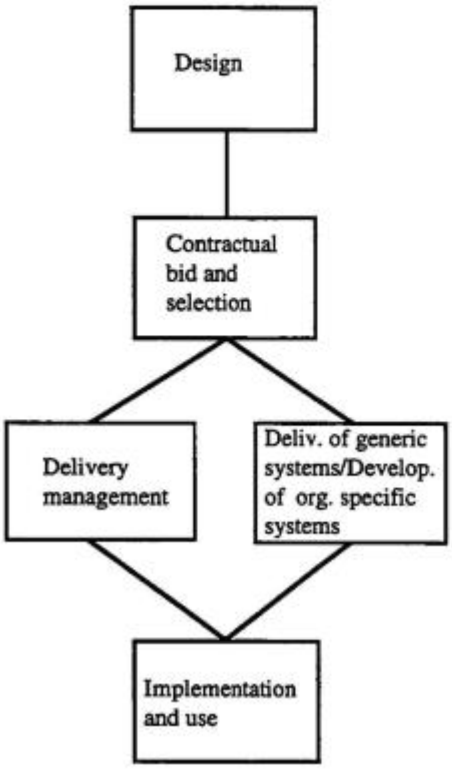


Figure 4. *EPCglobal Future Architecture Model*

The EPCglobal Future Model of Architecture is currently only one aspect of the broader IoT. However, it is currently being considered as the most promising and comprehensive architecture in the field of IoT (Uckelmann, 2011). The framework depicted above originally follow eight key building blocks considered as extensions to the EPCs. However, we have had to exclude two out of the eight extensions, due to lack of relevance. The two excluded extensions are; *Extended – federated discovery services* and *interface to federated billing services.* Note that in this thesis we will primarily focus on the extensions, However, we have been able to evidently proof that the EPC is an integral part of the solution proposal (see appendix; 6 – ISO Container ID). The six included points are as follows; *Extended static data support, Integration of dynamic data, Support for non-IP devices, Integration of an actuator interface, optional integration of software agents* and *data synchronization for offline support.*

MUST Method – Participatory Design

The MUST framework was developed by the Danish researchers; Jesper Simonsen, Finn Kensing and Keld Bødker. The MUST method was developed as their research had identified that most organization did not effectively use the software installed in their organizations. This was in a lot of cases since the business requirements were not adequately understood by the IT teams developing the software, meaning what was delivered in terms of software did not align with the expectation set by the business in first place. Hence, the MUST method has been formed, it has been developed through working closely with real life projects. The method is coherent in the sense that it deals with all activities within the application area: Analysis of needs and possibilities, establishing the vision for change, project management and planning for technical and organizational implementation (Simonsen, Kensing and Bødker, 1996). One may assume a model dating over 20 years back would be outdated and hence question the value derived from applying the same. However, one would be surprised to see the amount of misalignment there still exist between IT developments and business requirement (Please note this is a personal assumption, based on the experience of working with several development projects within ML and



APMT domain). The overarching process of the MUST method is depicted above, in this thesis we are proposing a designed solution, therefore we could not justify including the *contractual bid and selection* stage of the process model. This limitation is driven by the fact that we did not have any data support the stage, as we have not proposed the solution to ML and APMT management and hence haven't gone through this stage. However, note that this is an inevitable stage that must be followed in a real-life setting. Our application of the model will focus on ensuring alignment between IT and business requirements, through participatory design. The Method presents six principles that offers a set of techniques and ways of representing current work and the envisioned computer based systems. Each principle is considered indispensable and they are as following; *(1) participation, (2) close links to project management, (3) design as a communication process, (4) combining ethnography and intervention, (5) Co-development of IT, work organization, and users' qualifications* and *(6) sustainability.* Each of these six principles will analyzed throughout the analytical section of this thesis. And the analysis will assume that we have been conducting, driving and developing the design based on the interviews, observations and research that we have conducted in the organization. Ultimately assuring that the proposed solution is based on a participatory design.

Figure 5. *MUST Method*

We have now understood the theoretical framework which lies the foundation for the further analysis, in the following section we will present the solution and hereafter we will initiate our analysis.

The solution

To establish a thorough understanding of what the proposed solution entitles, we will in this section outline the solution in a high-level process framework. Each of the building blocks will be analyzed at a more granular level in the last section of the technical analysis. The high-level process framework is illustrated as below, to ease the interpretation of the process we have assigned a number to each of the steps. Each of the steps will briefly be described throughout this section of the paper. As mentioned during the introduction, the proposed solution will only cater for the import part of the shipping cycle. More specifically from the pre-berth event; 2 hours prior to the vessel is berthing - until the container has been unloaded and placed in the container yard for storage and demurrage.

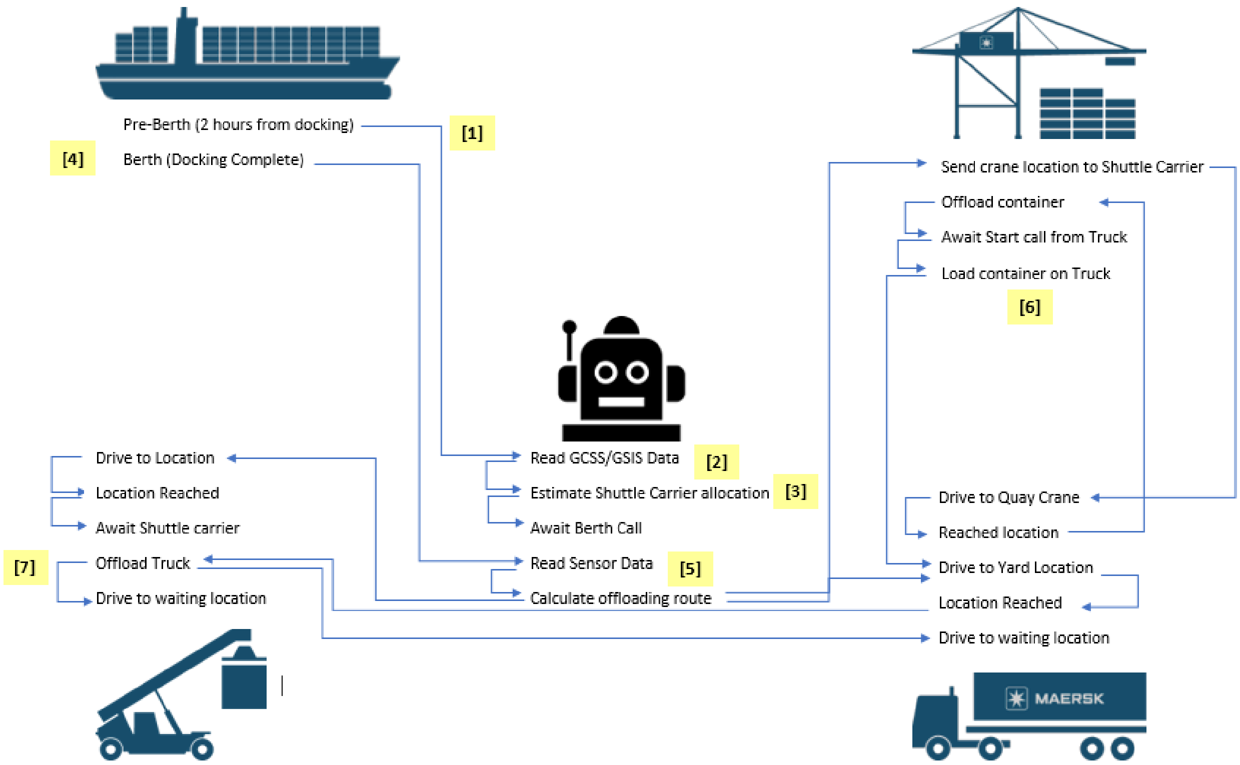


Figure 6. *High-Level process design*

[1] Pre-berth trigger

The starting -and entry point for the software's interaction is when a given vessel is approximately two hours away from docking. A legacy system in the ML application landscape called "Rederiets Kontainer" Event Manager (RKEM), has an in-built event that is currently being triggered two hours prior to a vessel is reaching the dock. RKEM is a mainframe application and is capturing all events in a container's end to end cycle. As the event will be triggered it will be transmitted to the software robot component, which is depicted in the middle of the process model. The robotic component will acknowledge that the event trigger has been received.

[2] Pre-berth trigger received – data enrichment

Once the RKEM event has been received and the robotic component have acknowledged the received input. The robotic software will make two data enrichment calls to two different ML legacy applications. First call that is being made is to the Global Schedule Information System (GSIS). Based on the event trigger received from RKEM, GSIS will identify which specific vessel voyage the trigger belonged to. The second call is made to the Global Customer Service System (GCSS). Based on the GSIS data of the specific vessel voyage, GCSS will enrich the software robot with shipment booking data that are part of the specific vessel voyage. Based on this the robotics software understand which Vessel that is incoming and which bookings (and containers) that are part of the specific vessel.

[3] Estimate shuttle carrier allocation

Based on GSIS (Vessel voyage) and GCSS (Booking and containers part of the vessel voyage) data the software robot is enabled to estimate the number of containers that is to be unloaded at the given terminal (in this setting Aarhus Havn). Once the estimation has been completed, the robotic software will assign shuttle carriers for unload activities. This will ensure a plan where in there are sufficient Shuttle Carriers assigned to a specific QC, which in turn guarantees the least stand-by time for the QCs (as it will constantly have a shuttle carrier to load a container on top of). Please note that the allocation estimation is done ahead of the vessel reaches the dock, it is done proactively to ensure the most efficient schedule and allocation plan for the shuttle carriers.

[4] Berth – Docking complete

Once the vessel has berthed and the docking has completed a secondary RKEM event is being transmitted to the robotic software, this event will indicate that the docking has been completed. The robotic software will acknowledge that the event has been received and will initiate the unload procedures. Software Robot calculate unloading route and sent route to Quay Crane.

[5] Read sensor data – estimate unload route

Once the vessel has berthed at the dock the automated QCs can start estimating the unload route for the containers placed on the given vessel. The unload estimation is based on container placed on the vessel and it will calculate the most efficient unload pattern. In our preliminary research, we assessed the possibilities of connecting the QCs and containers through NFC, however the technology is insufficient and would not enable us in achieve what we are aiming at. Hence, the connection between the QC and the container will be through a GPS signal, which is currently already installed in a large part of the container fleet[1]. Once the estimation has been completed the robotic software will communicate to the automated shuttle carriers the unload pattern and timestamp for expected unload from QC to the given shuttle carrier. Based on the unload route/pattern, QC location and timestamp the shuttle carrier have the needed information to align themselves correctly and timely.

[6] Container unloaded, shuttle carrier drive to container yard

At this stage in the process the container has been unloaded on the automated shuttle carrier. In the data enrichment call made in point [2] of the process the booking details was being fetched from GCSS. As part of the payload of data received from GCSS (booking details), the central software robotic component have understood the amount of last free days. Based on the amount of last free days the shuttle carrier can take an informed decision on which section of the container yard to place the container in. One of the problem statements identified was that there is a lot of manual coordination and relocation of containers in the container yard. This is because the manual operator is taken uninformed decision on where to place the container. Causing a lot of coordination and movement of the same container forth and back. In the proposed solution, the shuttle carriers will on basis of the last free day have a clear identification of when the customer expects to pick up the container and hence the shuttle carrier will be placing the container in clear divided sections based on last free day and expected pick up date. We propose to divide the container yard into eight sections, one section for each week-day and one section for long-standing container (more than seven days). The automated shuttle carrier will drive to the identified section to have the container unloaded by a Reach Stacker. Once the container has been unloaded the automated shuttle carrier will drive to waiting position at the QC side to await the next container load.

[7] Reach Stacker crane pick up container from shuttle carrier

Once the automated shuttle carrier has identified and driven to the right section of the container yard. The GPS technology that are installed in containers will be used for alignment between the automated shuttle carriers and automated gantry cranes. The last free day data is being transmitted from the central robotic component to the reach stacker as well, enabling them ahead of real-time to schedule which location the container will be placed in. The Reach Stackers will be enabled to take informed decision based on the last free day data, as to which section and stack the container should be placed upon. Once the Reach Stacker

[1] Currently GPS and Sensor data is only installed in Reefer Containers, however there is currently a project named: Dry Container Management (DCM), this project has set out to GPS and sensor data enable all dry containers as well. Hence this thesis builds upon the assumption that all containers have already been IoT enabled.

crane has stacked the container, the Reach Stacker will drive to the waiting position awaiting the next container receival from the automated shuttle carriers.

The proposed solution above is a mixture between a centralized software robotic component and physical digitized assets - industry robots. The software robot component acts as a centralized middleware layer, conducting the transmission of information and data to each of the physical assets / robots. Furthermore, it has to be mentioned that the solution will touch upon both APMT and ML domains. ML domain for data enrichment and APMT for operational terminal procedures. The solution will be validated against the identified *problem statements* after the analytical section has been conducted. This will help the reader in identifying which tangible issues that have been facilitated and spanned across based on the solution.

Analysis

Business case

Financical appracial

In Aarhus Havn there are currently eight Quay Cranes installed at the harbor to unload the containers from the vessels. Each crane can at current state on average unload 35 containers per hour. Each year more than 600.000 containers are being unloaded by Aarhus Havn's QCs. (Aarhus Havn, 2018)

From these numbers, we can estimate that in order to move 600.000 containers per year if all eight quay cranes are manned each day all year, they must be actively moving containers approx. 6 hours per day.

The calculation is as follows:

600.000 / 35 containers per hour = 17.143 Hours
17.143 hours / 6-hour active work time per day = 2.857 workdays
2.857 workdays / 8 quay cranes = 357 days

Having understood and showed that each of the eight QCs are active each day we can estimate how much it costs to operate the cranes. If we assume that each crane need two hours per day to align the crane with the ship, conduct maintenance, crane operator crawling up and down the crane and a lunch break. Based on this we can calculate the operating cost of each crane to be 12 Months * (Salary of crane operator + maintenance cost).

As the operator's salary is company sensitive data we will assume they have a salary of 35.000 DKK per month and the maintenance cost per month is 3.000 DKK. That gives us a total operating cost per month of 38.000

DKK per crane, which in total is 38.000 DKK * 8 quay cranes = **304.000 DKK Total Operating cost for Quay cranes per month**.

Next, we need to look at the current state for the shuttle carriers. The shuttle carriers drive with a speed of 15km/h and we have estimated that the average driving distance from crane to container yard is 500 meters. Furthermore, as each quay crane can unload a container in approx. two minutes then we estimate that each truck is holding still for three min when being loaded and unloaded.

If a Shuttle Carrier drives 500 meters with a speed of 15km/h

The mathematical equation is as follows;

60 minutes / 15 km = 4 minutes per km which means that 500 meters takes 2 minutes.

This means that each shuttle carrier use 10 minutes to have a container loaded, drive to container yard, get unloaded and drive back to the crane. As the quay crane unloads a container every two minutes, that means that it will take five shuttle carriers to keep a constant unloading flow and thereby having a 100% utilization of the quay crane. Now we know that each of the eight Quay Cranes need five Shuttle Carrier drivers six hours a day, this means that Aarhus Havn require 40 Shuttle Carrier drivers per day. Like with the QC operators we also assume that the truck drivers use the last two hours of their workday on lunch, maintenance, Diesel and going to and from the shuttle carrier. The last number we now need is the salary of the truck drivers and here we assume that they earn 30.000 DKK per month. With these numbers, we can now estimate the total monthly cost of truck drivers is 40 truck drivers * 30.000 DKK = **1.200.000 DKK Total Operation Cost for Shuttle Carriers per month**

Lastly, we need to look at the current run costs of the reach stacker cranes. The Reach Stackers can drive at 25km/h and for these cranes we assume an average driving distance of 300 meters and approximately three minutes to unload a shuttle carrier and two minutes to place the container at the desired location. It takes the Reach Stacker 0,72 minutes to drive 300 meters, which means it takes 6,44 minutes for the Reach Stacker to go to the desired location, unload the Shuttle Carrier, place the container and drive back to waiting position. This information tells us that there is a need for four Reach Stackers to unload a vessel in order to keep a constant unload flow and there is eight Quay Cranes so that gives us a total of 32 Reach Stacker Drivers. We make the same assumption with Gantry Cranes as with the other hardware, that two hours per day are going to be spend on other activities then actively driving and placing containers. We also assume that that the Gantry Crane drivers have a monthly salary on 32.000 DKK. We can now calculate the total monthy cost. 32 Gantry Crane Drivers * 32.000 DKK per month **= 1.024.000 DKK Total Operation Cost for Gantry Cranes per Month**.

The current run costs per month for Quay Cranes, Shuttle Carriers and Gantry Cranes are:

Quay Crane: 304.000 DKK

Shuttle Carriers: 1.200.000 DKK

Gantry Cranes: 1.024.000 DKK

Total Monthly Cost: 2.528.000 DKK

Total Yearly Cost: 30.336.000 DKK

Next, we will estimate the build and run costs for our initiative. To estimate the price of automating the Aarhus Havn terminal we are relying on the estimates made by the Director of Long Beach Port in Los Angeles, Gene Seroka. Long Beach Port are currently undergoing automation of their terminal activities and thereby have great insight into the cost of automating a terminal. Seroka estimates that an automation of terminal cost approximately 2.000.000 USD per acre (Dillow, 2018). The Maersk Terminal area in Aarhus Havn is approximately 50 acres which means that automation would cost around 100.000.000 USD.

The build cost of automating Aarhus Havn is: 630.000.000 DKK

Looking at this huge build cost it is important to keep in mind that this is the build cost for the first automated terminal, if and when Maersk choose to scale this to other terminals the build cost per acre will be greatly reduced as all the IT infrastructure and licensing does not have to be re-purchased for other terminals. In the new terminals, only the hardware will have to be purchased and installed to work with same IT setup as in Aarhus Havn.

The run cost is estimated to be reduced by 85% when having implemented the fully automated terminal. This is based on estimated cost savings from the Port Los Angeles project (Dillow, 2018).

Total Yearly Run Cost: 4.550.400 DKK

Total Yearly Run Cost savings: 25.785.600 DKK

Furthermore, the automated terminal is estimated to be able to increase productivity by 30% and as Aarhus terminal is currently active 24 hours per day 365 days per year we are assuming that the demand is there to use the 30% increase of productivity to take in 30% more containers in the terminal and thereby increase the revenue by 30%. **The revenue is at current sate on 85.600.000 DKK Per year**. Which means that **the automated terminal will generate additional revenue of 25.680.000 DKK.**

1.2. Sensitivity analysis

To analyze how sensitive the business is towards changes to the project, we need to look at difference between current cost and estimated benefits from doing the project as it is that space that indicates the sensitivity to changes. In our case the business is not very sensitive to changes as the run costs are being reduced so much that even if the build costs were twice as high the business will still earn money on this solution sooner or later. So, in this case the question is more about whether they can earn back their money before the technology gets outdated or used up so they need replacement before they have earned back their cost. However, the most expensive part is about changing all equipment to electric powered machinery and build the entire infrastructure around it so as long as that last is will be relatively cheap to change IoT components and those are just getting cheaper year by year (as illustrated later). To conclude on this the business is not very sensitive towards this project as the final result will give 30% extra revenue and reduce the run costs by 85%.

1. Project Definition

2.1. Background information

We will not explicitly cover the contextual background information at this stage of the thesis. Instead we refer to the General Introduction, Company Introduction, Problem Statement and Solution Proposal section of this paper. Herein the reader will achieve adequate information about the background and context of the project and the proposed solution.

2.2. Business Objectives

1. Communication gaps
2. Big boxes, big risk
3. Continuous learning
4. Container unload scheduling
5. Quay crane and truck alignment
6. Container Yard optimization
7. Eliminate the Human Factor
8. Go Green

For further understanding of the business objects we refer to the problem statement section where each of them are described in detail.

These business objectives feeds into the overall digitization strategy Maersk is currently aspiring towards. The top management is very focused on streamlining and ramping up the effectiveness of operation with new technologies to keep their market leader position in the shipping industry. This can be seen in recent statements from Søren Skou (CEO of Maersk T&L) at Maritime Week 2018 in Singapore.

Delivering his keynote address at the Singapore Maritime Week 2018 Søren Skou said that A.P. Moller – Maersk's focus on new technologies will transform transport and logistics industries for the benefit of both customers and the greater global maritime sector. Furthermore, Skou described the impact of digitization on the container industry culture as positive. He pointed to the company's greater ability to improve customer experience with integrated online booking systems and instant price quoting tools, supply chain ecosystems benefiting from digitized information and simplified documentation flows, as well as new industry standards for downfalls and no-shows reducing costs and delays.

2.3. Benefits and limitations

Benefits	Description
Leveraging communication gaps	Our solution gives and integrated continuous information stream to all stakeholders of operation, thereby eliminating the issue that terminal ports make the operational stakeholders reliant on traditional radio and radar communication between captains, terminal operators, tugboats and other operational participants.
Optimizing unloading route	A computer can faster and more precise than any human can estimate an unloading route. This will reduce the unloading time.
Reducing Risk of Incidents	When no humans are involved in unloading the vessels there is no chance of humans getting hurt in the process.
Enabling container yard optimization	Enabling a software robot to read all the sensor data of containers and read booking data about what each container contains in seconds will enable more precise container yard optimization.
Improving Crane / Truck Alignment	One of the largest waste buckets in terminal operations is the alignment process between hardware. However, our solution will greatly reduce this waste bucket as the robots are livestreaming data to each other through our software robot that will coordinate the un-/loading

	of containers with much higher precision than humans can.
Enabling continues learning	By having everything digitized we will have detailed operating data for most aspects of the terminal which will enable managers and operators to make data driven decision making.
Less training of personnel	Reducing the number of human workers in the terminal will result in less training of personnel as the software running the hardware is quickly trained by writing rules in the code on how to operate.
Eliminating human variance	Our solution will remove the human variance from the crane and shuttle carrier operations as it will be replaced by robots that can be programmed to operate more precise in a consistent manner.
Go-Green	As the proposed solution is changing the setup from diesel driven hard, to electronic driven hardware the carbon emission will be reduced. Furthermore, going green will reduce the run costs of hardware.
Reducing Run cost by 85%	As shown in the financial appraisal we will by changing from human labor to robots save 85% of the running costs.
Increasing revenue by 30%	Like above this is also taken from the financial appraisal where we learned that an automated terminal approx. will generate additional 30% revenue.

Table 3. *Organizational Benefits*

Limitations	Description
Only focusing on Import cycles	In our paper, we have only focused on unloading the containers from Ship to Shore and not loading the vessels from shore to ship.
Forecasted Costs	costs associated to physical quay crane operation (people), digitization costs (of terminal hardware), costs associated to software development and integration to physical assets in terminals. This have been it difficult to form a granular cost-benefit analysis as our costs are mainly bound based on assumptions. However, we are achieving to show-case the method in which we would have done the actual cost-benefit (if we had the actual costs), hence we are satisfied with the achieved result.
No hands-on experience with terminal operations	As both of us are employed in Maersk Line IT we have had no previous experience with how APMT are operating in their terminals. We have done a lot of research to obtain knowledge about this area but reading will never be the same as having concrete experience with daily operations, so our knowledge might be limited in specific areas of operation.
Only focusing on automating 3 kinds of hardware	The terminals have a lot of different machinery; however, we have only focused on automation the minimum required machines to unload a container which is Quay Crane, Shuttle Carrier and Reach Stacker.

Table 4. *Organizational limitations of research*

2.4. Option Identification and Selection

In this section, we will identify the solutions at hand, to outline what we are striving to achieve in this paper. We have identified three approaches to the solution, and they are as follows; **Fully automated,** which is the solution described throughout this paper. **Semi-automated,** an alternative solution could be a semi-automated terminal such as Maasvlakte II, where the cranes are remote-controlled by humans from an operating facility inside the terminal. This solution does however not remove the human variance involved in aligning Cranes with containers and shuttle carriers. Furthermore, this solution still has a lot of Non-IP data sources as the humans are not connected to the internet and their performance is hard to capture compared to how you would capture performance of a hardware/software robot. **Manual,** similar to current as-is solution hence no foundation for selecting a solution that is similar to the processes conducted today.

2.5. Scope, Impact, and Interdependencies

Our current ***scope*** is only Aarhus Havn as a test terminal for this project, but if the project proves a successful this project could be scaled out to other terminals as well. Within Aarhus Havn our scope is the QCs, Shuttle Carrier, Reach Stackers and lastly a software robot to coordinate and enable automation is within our scope for our automation of Aarhus Havn project. ***Impacts*** from this project will be a combination of the benefits and the financial appraisal which is described earlier in the business case. In our project, we have two kinds of ***interdependencies***. The first being the interdependencies between business units and the second one being the interdependencies with equipment in Aarhus Havn. The interdependencies between business units are between; Maersk line, APMT, Damco and Maersk Container industry. The project has interdependencies towards many business units' due to the fact that all of the business units deliver valuable data that are being used by the software robot. Interdependencies within Aarhus Havn is between the Quay Crane, Shuttle Carriers, Reach Stackers, Containers, Vessels and the Software Robot. As we are planning to fully automate the terminal, all the equipment within are depending on each other to be able to communicate together and to work closely together.

1.6. Outline Plan

The high-level plan is presented in below diagram. The feedback loop depicts the on-going iterations that the software development will follow, this is in accordance with the Scrum Agile methodology (which is covered in below section; *Project Approach).* The linear timeline, that continues after the loop is covering for the waterfall based approach, which we intend to deliver the IoT enabled digitized physical assets in. *See outlined plan below.*

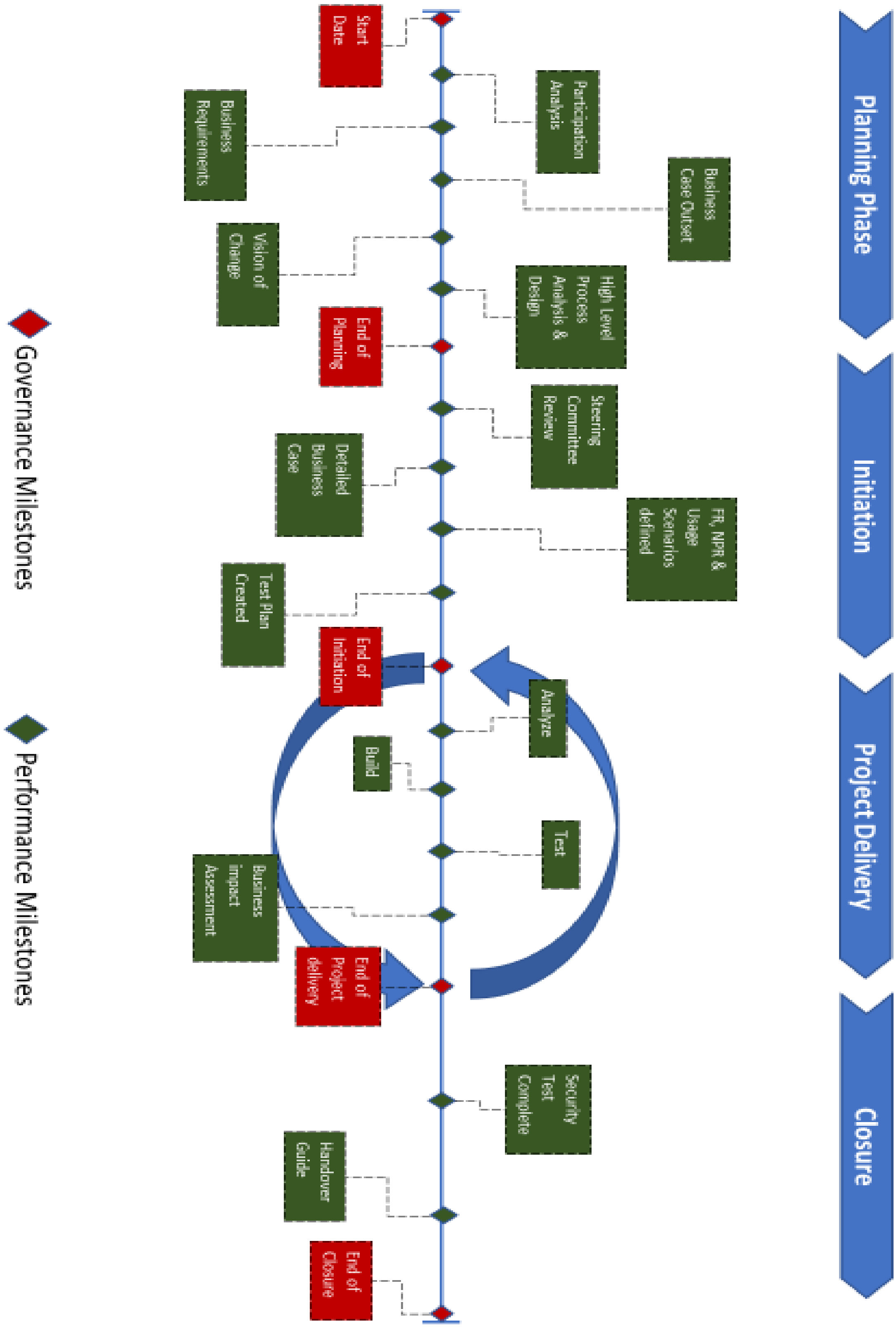


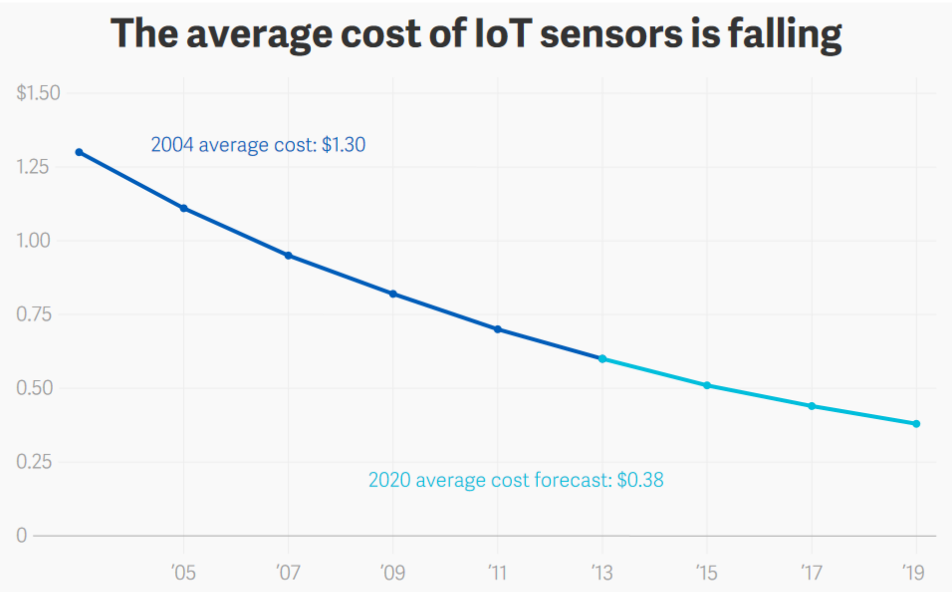
Figure 7. *Project Plan, Iterative + Waterfall*

2.7. Market Assessment

For the market assessment, we have chosen to use PESTLE to analyze the current market situation for freight terminals. We use the PESTLE analysis due to its wide span of factors in the market that can affect the companies operating in that market.

PESTLE — political, economical, sociological, technological, legal, and environmental — analysis.

Political	Politics play a big role when it comes to the terminal market, such as how to handle flammable cargo and other dangerous cargo. Furthermore, there are more and more focus on robotics and how we in the future will handle that robots might be taking over a lot of human labor, with the risk of leaving humans without jobs (Lanier, 2013). Another political factor is the many trade agreements that exist between countries today. One example is EU where we have special taxation rules when the countries trade with each other. A political risk that may arise is the protectionist approach that America is currently taking towards their foreign trade policies. This could ultimately impact the amount of container's Maersk will be shipping from e.g. China to America. Lastly a political factor such as putting sanctions on countries has a huge impact on the shipping and terminal market as it becomes illegal to trade good to and from the sanctioned country.
Economical	The globalization of the port industry has also strongly changed the traditional practices in which the traffic lines and carriers of a country favored certain ports. The arrival of containers into the global freight traffic and the increasing trade with Asia have broken the traditional concept of scale. So that currently, there is only one acceptable criterion for carriers and shippers, which involves that their traffics move by routes that offer the best results in terms of the global provision of the service and, in particular, in economic terms.
Sociological	• The sociological aspect in the Terminal industry is currently very focused around replacing humans with machines. A company like Maersk that have some strong values that surround all their business decision especially must think hard about how it will affect their brand when replacing humans with machines. Maersk have some core values

	that were written down when Mr. Mc-Kinney Moller, stepped down as CEO of Maersk, the core values are: • Constant Care • Humbleness • Uprightness • Our Employees • Our Name Especially the two last values are involved in the sociological aspect of changing people with machines for Maersk specifically but in the industry in general, the evolution is going towards automation, so if Maersk want to keep their good position in the market, they need to keep up with the technological advancements in the industry.
Technological	In recent years the use of IoT devices have exploded which have resulted in rapid evolvements within the IoT industry, which in turn has lead to decreasing prices for IoT devices as depicted below.  (https://www.theatlas.com/charts/BJsmCFAl) The cheaper prices of IoT devices is a technological factor that greatly affects our solution as the automation of the terminal relies on many types of IoT sensors.

	Technological developments have advanced in such a way that the units of transport are getting larger as they try to respond to the process of containerization. This technological progress, with greater capacity and power of the ships make more efficient journeys and require, therefore, larger port developments. In the maritime sector, we also find a remarkable risk of obsolescence, because of the recurrent necessity of updating the fleet of ships, equipment and navigation systems and, onshore, machinery and technology for proper loading and unloading operations. This necessity is created not only to meet the environmental and safety requirements, but also to keep some efficiency levels in order to stay competitive in the marketplace.
Legal	Legal factors are in our case closely linked to the political factors mentioned earlier. One additional legal factor that is worth mentioning is legal factors in can be different from one terminal to another depending on the country.
Environmental	In general, across industries there is a growing focus on being environment friendly in how business is operated. This also goes for the Terminal industry. Maersk Terminal have already made their first environmental sustainable terminal in Netherlands, the Masvalkte II Terminals runs entirely on green energy as also mentioned in the Maersk History earlier in this paper.

Table 5. PESTLE Framework

Project Risk Assessment

The risk assessment provided in this following section, will only take account of those risks that we have been able to identify prior to the project's establishment. It must be noted that risks will arise as the project development progress, these we have not been able to identify or cover for as we have only been moving in the pre-planning phase of the project.

Automation of Quay Cranes

Throughout our close work with the ML and APMT automation teams and especially Head of Automation Alexandru Duca. It was brought to our attention that there is currently no existing solution for a fully autonomous QC. However, it is currently possible to remotely control a QC through two joy-sticks and hence we suggested that the operation of these joy-sticks could be maneuvered through artificial intelligent software. Alexandru Duca agreed that this was an opportunity, but currently not available in the market. Hence, we have identified this as a risk (but also a major opportunity).

High costs

There are high costs associated with the proposed solution. Especially the digitization of the physical assets is a long-term investment and as such there are no guarantees that the fully automated process will achieve better performance than what is currently achieved in Aarhus Havn. So, we would argue that a known risk is that we are not able to identify or conclude if APMT and ML will be able to materialize and benefit from the investment.

Conservative industry

Alexandru Duca stated that the maritime shipping industry is conservative in nature, this does not mean that the industry itself is reluctant to change; "It means we are just very slow at changing" (Alexandru Duca, 2018). Moreover, once a project set out to make major changes to the terminal and shipping infrastructure the effort required is extensive, hence there is an existing mindset within the industry; "if it is not broken, why fix it" (Alexandru Duca, 2018). This means that it may be difficult to get the required buy-in from management to aspire towards a solution that will revolutionize the ways of operating the activities in scope of our solution.

2.9. Project Approach

Our project of automation the terminals will consist of two sub-projects. One being developing the software robot that are going to read data from Maersk's Data Lake and calculate fastest route for the hardware robots. The other project is concerned with installation of the hardware that needs to go into the cranes and trucks to make them into hardware robots.

For the Software robot project we would recommend running as an agile project as it allows for continuously improvement and every two to eight weeks you deliver a tangible product that can be tested and verified by business users. The agile framework that are currently being used in ML is Scrum Agile. This framework was developed to improve the way software projects is being done as you can easily adjust code and write incremental improvements along the way and that will result in software with a higher quality than the original software you planned to create. We would of course like to utilize the Scrum Agile framework to unlock some of these benefits and end up with the best software product as possible.

The Hardware Robot project we will approach differently as there is a vast amount of manual installation of sensors, drivers and other IoT devices that will become too costly if you run that as an iterative process where you can add improvements along the way that might result in that you need to but new sensors or other hardware. The hardware robot project will benefit more from a Waterfall project approach as we see it as all needs to be mapped on how the different sensors will talk together and what hardware is necessary and then they will all be implemented at the same stage of the project. This will save this project a lot of money and simplify the process as you don't have to continuously go back and change the documentation to capture all the interdependencies between the different hardware. After having implemented the hardware robots in the terminal it could make sense take an agile project approach to improving the robots at a later state in time.

Cost Benefit Analysis

After having done the business case for this project wherein we have analyzed the financial costs and benefits for the project, we can now give a good overview of economic justification of automating the Aarhus terminal. The overview we will give by doing a cost / benefit analysis. As you can see below we are doing the cost / Benefit in a tabular format for the first 10 years of the projects lifetime.

Year	Cost	Benefit	Net Benefit	Description
0	-630.000.000 DKK		-630.000.000 DKK	Cost = Total Build cost of project
1	-4.550.400 DKK	51.465.600 DKK	46.915.200 DKK	25.785.600 DKK (Yearly Run Cost Savings) + 25.680.000 DKK (Additional yearly revenue) = Total Benefit
2	-4.550.400 DKK	51.465.600 DKK	46.915.200 DKK	
3	-4.550.400 DKK	51.465.600 DKK	46.915.200 DKK	
4	-4.550.400 DKK	51.465.600 DKK	46.915.200 DKK	
5	-4.550.400 DKK	51.465.600 DKK	46.915.200 DKK	
6	-4.550.400 DKK	51.465.600 DKK	46.915.200 DKK	
7	-4.550.400 DKK	51.465.600 DKK	46.915.200 DKK	
8	-4.550.400 DKK	51.465.600 DKK	46.915.200 DKK	
9	-4.550.400 DKK	51.465.600 DKK	46.915.200 DKK	
10	-4.550.400 DKK	51.465.600 DKK	46.915.200 DKK	

Table 6. *Cost Benefit Table*

Next, we will give a visual representation of when the benefits will be greater than the costs of the project. We are doing that by adding two columns to the table above and add the accumulated cost and the accumulated benefits. The table can be found in appendix 1.

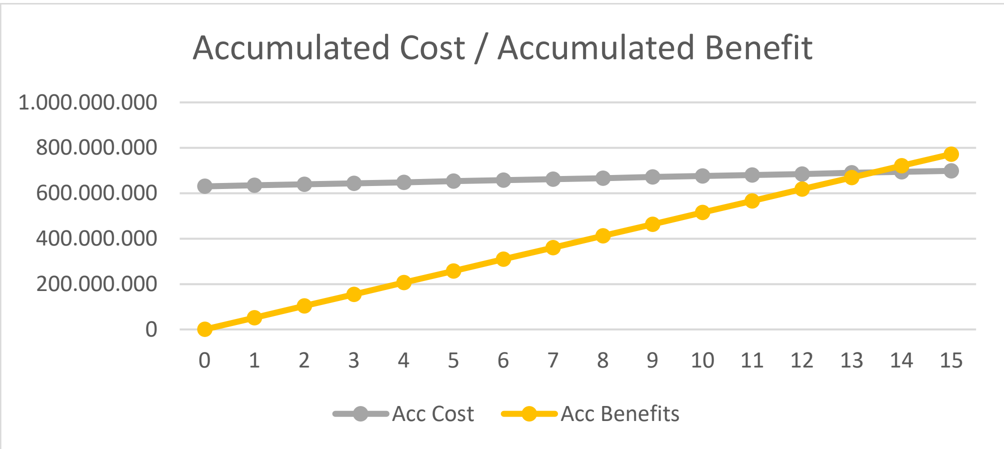


Figure 8. *Cost Benefit Cutover*

As shown in Figure 8 the project will have paid itself off and start earning money after 13,5 years. As mentioned earlier in the business case the build costs of implementing this project in other terminals would be less than for the first terminal, which means that if they start to roll this project out in other terminals the overall project of automating terminals will payoff faster than the 13,5 years for Aarhus Terminal alone.

Business Model Canvas

In the following, we will base our analysis on the framework by Osterwalder and Pigneur (2009), which is referred to as the "business model canvas". The applicability of the model is proven by its use in practice, but it has also been referenced by a number of publications (e.g., Chesbrough 2009).

The business model framework includes four main perspectives of the business model, namely the *product, the customer Interface, financials and the infrastructure management*. These four perspectives are a way to split the Business Model Canvas into simple sections that are tightly linked together. The components are not stand-alone but mutually influence each other.

Product:

In our Business Model, the main value we offer the business with our product is:

•Boost productivity with 30%*

• Decrease run cost by 85%

•Automated and Simple unloading

•Safe Unloading

•Environment Friendly Terminal

• Consistent operation

This value is largely generated by having robots that are consistent and efficient in operation and also by the continuously stream of data from all the IoT devices in the terminal. Providing the right information has a huge impact as it lets management know what the waste buckets are, as Alexandru Duca said in our interview "The biggest waste bucket is that we don't know what and how big all the waste buckets are as we don't have any data on it, due to the fact that large parts of operation is done by humans". IoT devices in the hardware robots will at all time send accurate information about the operations and if there are any waste buckets involved in their operation is will be transparent for management to see as the data is captured in the system.

Customer Interface:

Our Customer Interface should be very automated and professional, our solution when activated is running 24 hours per day and therefore we need to eliminate as many manual processes as possible with our smart product/service. Our customers interactions with our product should happen through a digital interface that allows them to interact with it on their time and gives them the opportunity to monitor the service we provide in terms of our product. Furthermore, we offer interfaces for both mobile and pc devices to give the easiest customer Interface as possible.

Financial Aspect:

The finance part of our Business model is partly to increase the productivity of the terminal operation and thereby gaining additional revenue and partly by reducing the Run costs of the operations. We also make a pay-per-use system that allows us to charge other vendors that want to use our IoT enabled infrastructure.

Infrastructure Management:

The last section is the Infrastructure Management and here we show what our main activities are and who/what is helping us to do those activities. Amount our many activities the key activities is to automate the operations, reducing the incidents happening in the Aarhus Terminal, Managing the containers and monitor the operations to generate reports for management to do data driven decision making and to make sure all equipment is operating as it should. The partners and resources that will help us execute on this is software partners, service providers and also all the hardware and IoT devices will enable us to do our key activities.

Key Partners:
- Server Partners (Microsoft Azure)
- Service Providers
- Data sourcing Partners

Key Activities:
- Automating the Terminal
- Reducing Incidents in the Terminals
- Container Management
- Monitoring

Key Resources:
- Fleet
- Quay Cranes
- Shuttle Carriers
- Reach Stackers
- IoT Infrastructure
- Data Lake
- Software Developers

Value Proposition:
- Boost productivity with 30%*
- Decrease run cost by 85%
- Automated and Simple unloading
- Safe Unloading
- Environment Friendly Terminal
- Consistent operation

Customer Relationship:
- Self- / Automated- Service

Channels:
- Internet (ML.com)
- Mobile
- Fysically at Aarhus havn

Customer Segments:
- Aarhus Terminal
- Maersk Terminals
- Other Terminals
- Shipping companies wanting to unload in Aarhus havn

Cost Structure:
- Reduced Staff Expenses
- Better Hardware Utilization
- Software Licensing
- Reduced Maintenance

Revenue Streams:
- Reduced Expenses (As every DKK saved is DKK earned)
- Payment for better tracking of Container
- Pay-Per-Use for other Shipping companies to use this terminal*

Figure 9. *Business Canvas of Proposed Solution*

Technical Analysis

The MUST Method

As mentioned throughout the theoretical framework, we will assess four out of the original five stages of the MUST method. 'Contractual bid and selection' has been excluded due to lack of information and relevance to what it is we strive to achieve at this point in time. We will emphasize the first step of design and focus on the alignment between ML and APMTs requirements this is done through the appliance of the six key principles of the method as well as assessing each of the five activities that constitutes design according to Simonsen, Kensing and Bødker. The activities that constitutes the design process will first be outlined, as to set a foundational outset for the further analysis of the participatory design. The academic paper consider Two teams; the technical team as IT Professionals (Developers, Architects and Analysts) and the Steering Committee (Management, Business users and Future Business Users). We would like to stress that in this research setting we have considered ourselves being the team consisting of IT Professionals, whereas the organizational research provided by interviewees and observations will form the input retrieved from a fictional steering committee.

Five main activities constituting the design process

To formulate a more granular approach for how to achieve a strong design approach and thus a strong project, Simonsen Kensing and Bødker suggests that a project is being designed around the following five main activities. Each of these activities will be seen in light of how we would aspire to apply them for the proposed solution, as if it would be implemented to the organization. The five points are as follows: (*1) project establishment, (2) strategic analysis, (3) in-depth analysis of selected work domains, (4) developing one or more visions of the overall change, and (5) anchoring the visions.* Simonsen, Kensing and Bødker states how each of these activities produces knowledge which will allow the team of IT professionals to keep future users aligned with the design that is being aspired towards. The steering committee will in turn be enabled to focus on the decision making that allow the design team to understand the overarching design direction, which is a requirement for the design team to proceed. The close involvement of the steering committee, enables them to make decision on a qualified basis and thus minimizing risks in the ongoing interpretations of the project's goals and mitigating the risk of developing an unrealistic vision for the project (Simonsen, Kensing and Bødker, 1996).

<table>
<tr><td>Project establishment</td><td>The purpose of project establishment provides the steering committee, users and the IT professionals with a sound basis for succeeding project activities:
Scope and aim
End to end automation of container procedures, through IoT and Robotics software
Achieve operational excellence through leveraging the synergies between APMT and ML
Level of ambition
Revolutionize the ways of working with containers from discharge to storage.
Project planning
Refer to Outline Plan in business case section</td></tr>
<tr><td>Strategic Analysis</td><td>The purpose of the Strategic Analysis is to clarify and delimit which domains that are in focus of the project's design process. Simonsen, Kensing and Bødker mentions how this is often covered in the project establishment stage – which is the case in this thesis.

To elaborate further, the overall strategy that we set in, was to resolve each of the identified problem statements for APMT and ML.</td></tr>
<tr><td>In-depth analysis of selected work domains</td><td>The purpose of the in-depth analysis of selected work domains is to understand the present issues with the as-is ways of working, again we refer to the section of problem statements, wherein we identified the issues at hand related to the operational procedures conducted by both APMT and ML.</td></tr>
<tr><td>Developing visions for the change</td><td>The purpose of developing the visions for the change, is to ensure that all participants whether being Steering committee or IT professionals – are aligned in terms of what is aspired towards. As mentioned earlier in this have been clear for all participants at all the conducted activities both in terms of interviews, observations and co-analysis sessions with included interviewees. The vision of the change are as follows:

End to end automation of container procedures, through IoT and Robotics software</td></tr>
<tr><td>Anchor the visions</td><td>Excluded as we have not been enabled to anchor the visions of the proposed solution as we have been limited in doing the actual roll-out to the organizations.</td></tr>
</table>

Table 7. *Five Main Activities that Constitutes a Design Process*

Principle 1: Participation

A large proportion of software that is being developed and installed in organizations is never being used, in most instances this is because the IT professionals have not got the requirements right (Simonsen, Kensing and Bødker, 1996). Simonsen, Kensing and Bødker have identified participation as a way to increase the probability that a design corresponds to the requirements presented and hence ensuring a system that will serve the intended purpose and be used as intended. It is vital that the IT professionals (who develop a given system) have the required knowledge of the usage scenarios of the system being developed. This would mean in our case it is a pre-requisite for the IT professionals to have a thorough understanding of the operational procedures conducted at the terminal site. Furthermore, it is important for the future business users of the system that they have a view of the technological options available, the technological overview should be developed for the business users in a co-learning process right (Simonsen, Kensing and Bødker, 1996). This will enable the business users to provide valuable inputs during technology selection and address e.g. limitations of a technology which would not be perceived in the eye of an IT professional. The participatory design phase is ultimately driven by the IT professionals and apart from being technical focals, it is also vital that IT professionals together with management communicate and clearly anchor the vision that is aspired towards. The participatory design facilitation and vision of this solution for ML and APMT have clearly been anchored prior to all interview conducted; we want to fully automate the container procedures from pre-berth till container has been placed in the container yard. By having a clear vision participants have been very clear on the agenda and have been able to support and assist with beneficial knowledge that has brought us closer to the final solution. Unfortunately, in this thesis we have been limited in engaging with business personnel and hence we have not been able to test the participatory design process with them. But we trust that the participatory design conducted with subject matter experts from IT, design teams and automation directors have been sufficient to validate and verify the usefulness of participation in the design phase.

Principle 2: Close link to project management

The project management of this given project, or any other project, deals with the division labour; how the project is being designed, the process of doing the same and clear procedures for how arising conflicts and risks are mitigated. Simonsen, Kensing and Bødker states in their paper that the team of IT professionals deliberately should establish a strong bond with project management. Further, they advocate that a clear division of labour between the design team (IT professionals) and a steering committee (consisting of management and future business users) is established. In this research setting we consider ourselves as being members of the design team, as we have carried out the project analysis, design and committed thought management around the technical implementation to the organization. The steering committee have not been a visible factor throughout the research and writing of this paper, however as mentioned above it would be a team of managers and future business users. This aligns with the participation mentioned during the first principle above – ensuring participatory design. In a potential implementation setting for the proposed solution a tight link to the management would be vital, as the solution for this project is extensive in nature and has a lot of different stakeholders through each of the segmentations we are proposing change for. Each of these stakeholders would have to be represented in the committee to avoid the pitfall of missing the aspired business requirements.

Principle 3: Design as a communication process

The third principle deals with the communication processes that has to be established between IT professionals, users and a steering committee. The communication model is divided in three different segmentations; *user's present work, new system* and *technological options,* each of these segmentations are seen in the light of *abstract knowledge* and *concrete experiences.* At the outset users and the steering committee will have knowledge around their current work and the organizational options - this relates to the *User's present work*. Whereas IT professionals and the design team have a knowledge around technological options available – this relates to *Technological options*. The segmentation in the middle *new system* is the envisioned technology in relation to the domain that is being assessed for change. Simonsen, Kensing and Bødker states that the abstract knowledge is required in order to get a high-level overview of the domain, whereas the concrete experiences are required in order to understand the abstract knowledge and evaluate its relevance. Each layer of the communication model is outlined in below table (table 8), the points included in this is both the technological outset and the outset presented of the current ways of working from users and the steering committee. Simonsen, Kensing and Bødker states in their paper that it is important that the communication between IT professionals and the steering committee constantly evolves through small iterations (Simonsen, Kensing and Bødker, 1996). These iterations should evolve between the abstract – and concrete layer. How we have interpreted this is that; what is known at the abstract layer, must be turned into a concrete experience. The way we have identified to do this is to follow the Agile Scrum methodology for development, specified further in the *project approach* of our business case section. Meaning that the new system based on steering committee inputs and the technological options (and IT professionals input), will be developed and showcased in small iterations, in order to ensure a constant alignment of what is being delivered is according to the requirements identified. It is however to be noted that the digitization of the physical assets must be delivered in a waterfall-like approach, as there is not the same freedom, as in software development, to iterate forth and back on what is being developed in terms of physical assets. The nature of the iterative approach will be further elaborated upon during the analysis of principle 4.

	User's present work	New system	Technological options
Abstract knowledge	• As-is container unload procedures • As-is container placement on shuttle carriers • As-is container placement in container yards	• Develop a robotics software that will coordinate and manage operational procedures fully – from pre-berth to container stored in container yard. • Digitize physical assets to act as smart, connected IoT enabled hardware.	• Software Robotics. • Internet of things, enabling physical infrastructure.

Concrete experience	• As-is container unload procedures.
	  ○ Manual unload procedures, difficult to achieve critical path of efficiency.
	• As-is container placement on shuttle carriers.
	  ○ Waste related to truck/crane alignment.
	• As-is container placement in container yards.
	  ○ Manual ordering of containers, causing wastes as a single container may be moved multiple times.
	• Risks related to operational work in the terminals.
	• Difficult to identify specific terminal pitfalls, hence difficult to plan for operational performance improvements.
		• *"As-is container unload procedure".*
		  ○ Software that can estimate and calculate most efficient unload route.
		• *"As-is container placement on shuttle carriers".*
		  ○ Digitized and automated shuttle carriers and QC alignment through GPS and sensor data.
		• *"As-is container placement in container yards".*
		  ○ Digitized and automated shuttle carriers and reach stackers can align themselves with each other through GPS and sensor data. Reach stackers are enabled to sort the containers in container yards based on sorting algorithm.
		• Risk reduction as limited manual interference in operational procedures
		• Data enabled knowledge based on digitized assets will enable continuous learning and increased performance.
			• *IoT components:*
			  ○ *GPS Technology.*
			  ○ *Sensor Data.*
			  ○ *Streaming architecture.*
			  ○ *Data sourcing from physical assets.*
			  ○ *Digitization of physical assets.*
			• *Robotic software;*
			  ○ Enterprise Service Bus, middleware integration knowledge (software connected with IoT devices).
			  ○ Service Oriented Architecture knowledge (development of webservices).
			  ○ Electronic Data Interchange (EDI) technology for transmitting data across systems

Table 8. *Iterative Communication model between Steering Committee and IT Professionals*

Principle 4: combining ethnography and intervention

By combining techniques of ethnography and intervention we enable ourselves in taking an iterative approach towards the design and development of the solution. Bloomberg et al. (1993, p125) states; *"to learn about a world you don't understand you must encounter it at first hand".* It is crucial for the team of IT professionals to develop a thorough understanding of user's present work in order for the developed design to realistically reflect the business requirements. The thorough understanding has in our research setting been achieved through ethnographic and observations (as detailed in our methodology section) of the present work and how it is being conducted. This has been a vital step laying a foundational knowledge that we have been able to base the solution building blocks upon. Just as important it is for the IT professionals to understand the setting in which they are developing a solution in, it is just as important for the users and steering committee to have an established and thorough understanding of the approach and direction the IT professionals are taking to the design (as also mentioned above in the communicative section, principle 3). We have achieved a mutual understanding of the direction, by having the solution formalized (in information diagrams, process diagrams and visions) prior to conducting an interview or observation, meaning that the business users and steering committee have been aware of the approach and hence have been able to partake in the discussion on a knowledgeable and qualified basis. Which in turn have enabled us to formulate a solution that iteratively target the problem statements as considered by the steering committee, ensuring a development space where requirements are met – not missed. Simonsen, Kensing and Bødker quote Mogensen (1994); *"other suggest the use of rapid prototyping".* It is evident in today's industry of software development that most projects are being developed in agile iterations, a cornerstone of the agile frameworks is that prototypes or Minimum Viable Products are showcased as quickly as possible, in order to ensure a constant alignment between business requirements and a mutual understanding for the IT professionals. Hence, this is also the approach that we would aspire to take if the actual developments were to be taken forward. Again, we stress that the iterative approach would only be taken for the development of the robotics software.

Principle 5: Co-development of IT, work organization, and users' qualifications

According to Simonsen, Kensing and Bødker new IT solutions are often introduced because the management of that given organization wants change to happen, to e.g. derive unrevealed organizational benefits, efficiency or control. However, a pitfall they have identified is that most organizations only focus on the technological aspect and forget that the system in first place need to complement your user base's qualifications and ultimately their distinct usage scenarios. The overarching key-point to be understood from the sixth principle is that we, as the team of IT professionals, must:

Plan and estimate the costs of the activities addressing technical, organizational and educational issues. The previous mentioned principles emphasizes the interrelation between development of IT and organizational development. The fifth principle emphasize the need of developing the users' qualifications and education of the same to ensure a coherent and valuable whole (Simonsen, Kensing and Bødker, 1996). And herein we stress that it is not the technical capabilities that has to be trained for, no. It is the distinct usage scenarios that a user will conduct on the system that has to be trained for. In our proposed solution, this would mean that users had to be trained in accessing, understanding and using the user interface. However, it has to be noted that since the developed system in our case is robot automated in nature, human intervention would be considerably less than for a normal developed system. However, our proposed solution would still have user interfaces wherein the user can access data generated from system in order to enhance the continuous learning problem statement defined earlier in this thesis. As well as a user interface where users can manually prompt executions from the IoT enabled hardware.

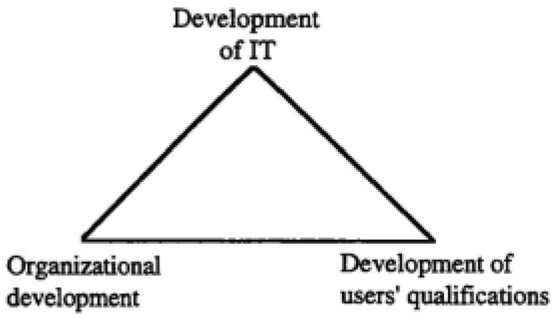


Figure 10. *Co-development in Related Domains*

Principle 6: Sustainability

Throughout the above six principles we have a set a foundation for developing a long-term sustainable IT solution. As mentioned previously throughout this analytical method, IT systems are prone to fail economically; either expected rationalization did not materialize or project run far over budget. I.e. in such projects, emphasis on enabling user qualifications and focus on aligning to the business requirements are often not being taken care of (Simonsen, Kensing and Bødker, 1996). The MUST method presents a coherent method for developing a IT solution that aligns with the organizational/user requirements, based on the large focus that lies within the framework on user participation. Furthermore, a key-point identified throughout the analytical method is that the steering committee and IT professionals will be best enabled by experiencing through practice. This again ties together with the proposed project approach of developing the solution is small iterations, in order to enable the user to modify and have a clear tangible experience of the requirements along the development process.

On basis of above analysis, we have thoroughly identified how participation can and should be used to achieve alignment between IT professionals and the steering committee. Participation and enabling the future users to experiment at an early stage is vital to ensure this constant alignment, ensuring what is being delivered is what is being asked for.

EPCglobal – Future Architecture model

As mentioned throughout the theoretical framework section of this thesis, we intend to apply the EPCglobal's Future Architecture Model to understand the six distinctive building blocks. These six components are in the following section analyzed and understood based on the proposed solution's IoT elements. Please note that each of the extensions below have been assigned a number that aligns to the numbering assigned to the model depicted below. The edge architecture connection is being thoroughly analyzed and described in the latter section of the analysis.

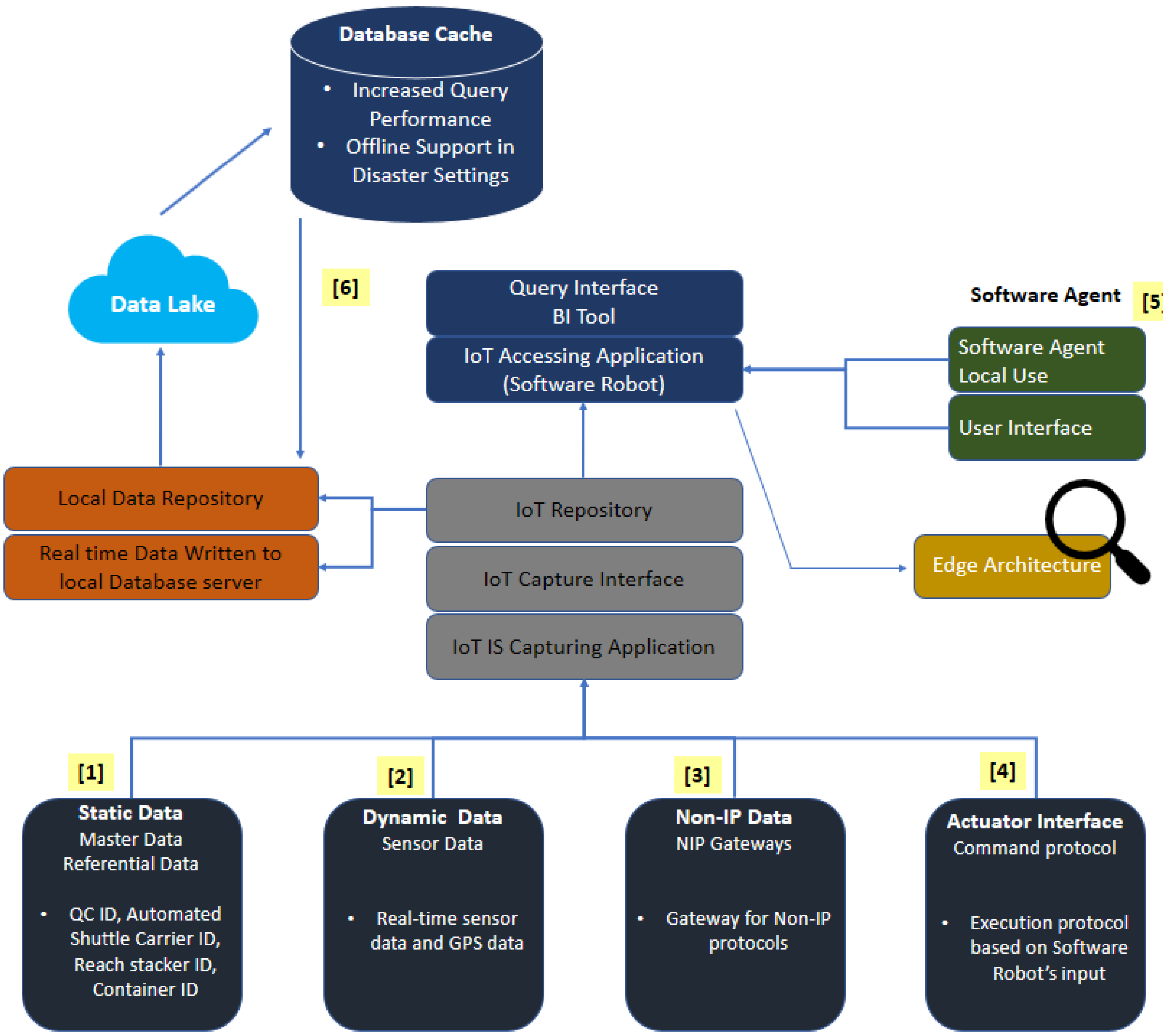


Figure 11. *Internet of Things Architectural Diagram*

[1] Extended static data support

Extended static data support is concerned with static referential data. In the proposed solution, it is considered as master data that would reside in legacy databases or a cloud-based data lake. The master data residing in either of these databases is used as unique identifiers between IoT enabled hardware components, e.g. Quay Crane ID, Automated Shuttle Carrier ID and automated yard crane ID. Based on these unique identifiers the machine to machine (M2M) can identify each other, and hence they are enabled to conduct the interdependent work procedures. The actual alignment in M2M interactions are done through sensor technology, but in order for the machines to recognize that it is aligning with the scheduled machine the unique identifier is required.

[2] Integration of dynamic data

Integration of dynamic data is concerned with the dynamic data that is constantly being generated in run-time. Uckelmann states that; in order to synchronize the real world and virtual world it is required for IoT enabled components to be able to sense environmental conditions as well as the status of the specific device or asset. Uckelmann continues and say that sensors are the key component for the coming generations of IoT. This is because; they empower a bottom-up interaction with things by enabling the gathering of information about their state or condition within the real world (Uckelmann, 2011). The state of things; QCs, Shuttle Carriers and Reach Stackers can for example generate real-time data enabling APMT and ML for predictive maintenance of their physical assets. E.g. an alarm system that will notify if there is an issue with any of the physical assets that are being IoT enabled as part of the solution proposal. Another example of dynamic data needed is for the QCs when they are lifting a container as part of the unload procedure, herein it is required for it to be able to measure the balance point in the container, only through dynamic sensor data the QC will be enabled to calibrate the weight point in real time. Furthermore, the dynamic data in the shape of sensor data will enable the assets to function according to the instructions provided by the robotics software. Ensuring that the automated vehicles (Shuttle Carriers and Reach Stackers) do not collide with one another. In the proposed solution, the dynamic sensor data is fed to the central robotic software through outbound query protocols enabling the decision making to happen at the robotics software layer of the solution.

[3] Support for Non IP-devices

Various types of sensors do not have the capability to be connected to the internet through a regular internet protocol connection. Hence Non-IP devices within the domain of IoT, will be connected to the Robotic software through gateways (Uckelmann, 2011). Unfortunately, we have been limited in doing an analysis of the actual sensor devices that we would install in the physical assets. Hence, we would not be able at this point in time to define whether the chosen sensors will be Internet Protocol compliant or not. In case they are internet protocol compliant the sensors would be connected to the robotics software through a regular internet protocol, whereas if not; the sensor data would be connected to the robotics software through gateways.

[4] Integration of an actuator interface

Actuator integration to the IoT domain will allow standardized communication with machines executing decisions either rendered by humans or software-agents, in our proposed solution it will primarily be rendered through a software-agent. However, there does exist distinct usage scenarios wherein the communication for execution will be rendered by human intervention in IoT domain (to be further elaborated below). Uckelmann states that the combination of sensors and actuators and their integration in the domain of IoT is an indispensable feature and will have to be considered at all layers of the architecture (Uckelmann, 2011). An actuator is the contrary to a sensor, yet very much complementing; *A sensor transform useful energy into electrical data. By contrast, an actuator transforms electrical data into useful energy.* This means that the electrical signals (data) generated when a QC has to calibrate the weigh-point of a container, is being executed at the actuator level of the architecture. The actuator is the actionable element in IoT. With only sensors, we would be able to generate vast amounts of data, but not be able to execute action automatically based on the generated data. This means that an actuator architecture has to be established for the physical assets being IoT enabled, in order for them to be able to operate and execute on the information generated from sensors.

[5] Integration of software agents

As outlined in the '*The Solution'* section of this thesis, one of the main building blocks of the solution is to have a centralized robotics software that will direct all the data inputs and inform the physical assets how to execute based on this data. This is the main software-agent, it will not be thoroughly explained in this section of the paper, but we refer to the latter section *(software robot, technical design)* wherein we will outline the technicalities of the software robot in further depth. In section however we would like to outline that apart from the software robotics there are In some distinct usage scenarios, it is required for an human agent to intervene in the IoT domain. Hence, there is a need for the to be able to interface with the IoT processes, this could for be through a computational software user interface. From the user interface, the human agent should be allowed to communicate with the IoT assets, in order for them to execute on basis on the decisional input provided from the human agent. An example of when the software user interface would be relevant is when a customer arrives at the terminal to pick up his/her container. Herein, a human has to trigger the automated Reach Stacker's to execute the activities related to fetching this specific container for the customer. This requires an accessible software user interface that can be easily accessed from the terminal site.

[6] Data Synchronization for offline support

It is extremely vital that the operational activities happen in a timely manner. A prerequisite for the activities to happen in a timely manner is that data is synchronized and shared across all the involved entities, to ensure data integrity. There may be certain cases where online-connectivity cannot be assured, if for example the ship is at sea. In the solution, we have an in-built cache that will cache relevant data regarding; discharge lists, stowage lists, vessel voyage details, booking details, etc. The data cache will be purged and refreshed on weekly basis. Once the data resides in the cache it will be available to all systems. Note that real time sensor and actuator data will not be available in case the internet protocol fails, or the gateways for the same. The cache will only ensure data integrity for the data that is being obtained from the legacy systems. And the cache will be based on the data that is being replicated from the internal database servers in the terminal, to the data lake.

Software Robot, Architectural Design

Throughout the *'The Solution'* section of this paper we outlined in a high-level manner how the system would function. In the above section, we understood the building blocks of the solution in a more detailed manner with regards to the IoT components. The below architectural diagram is made for the reader to get a better understanding of the data enrichment calls that is being made from the robotic software to legacy domain in ML (Point 2; in *'The Solution'*). Each of the 13 steps from the edge architecture will be briefly described below, with an emphasis on the used technology.

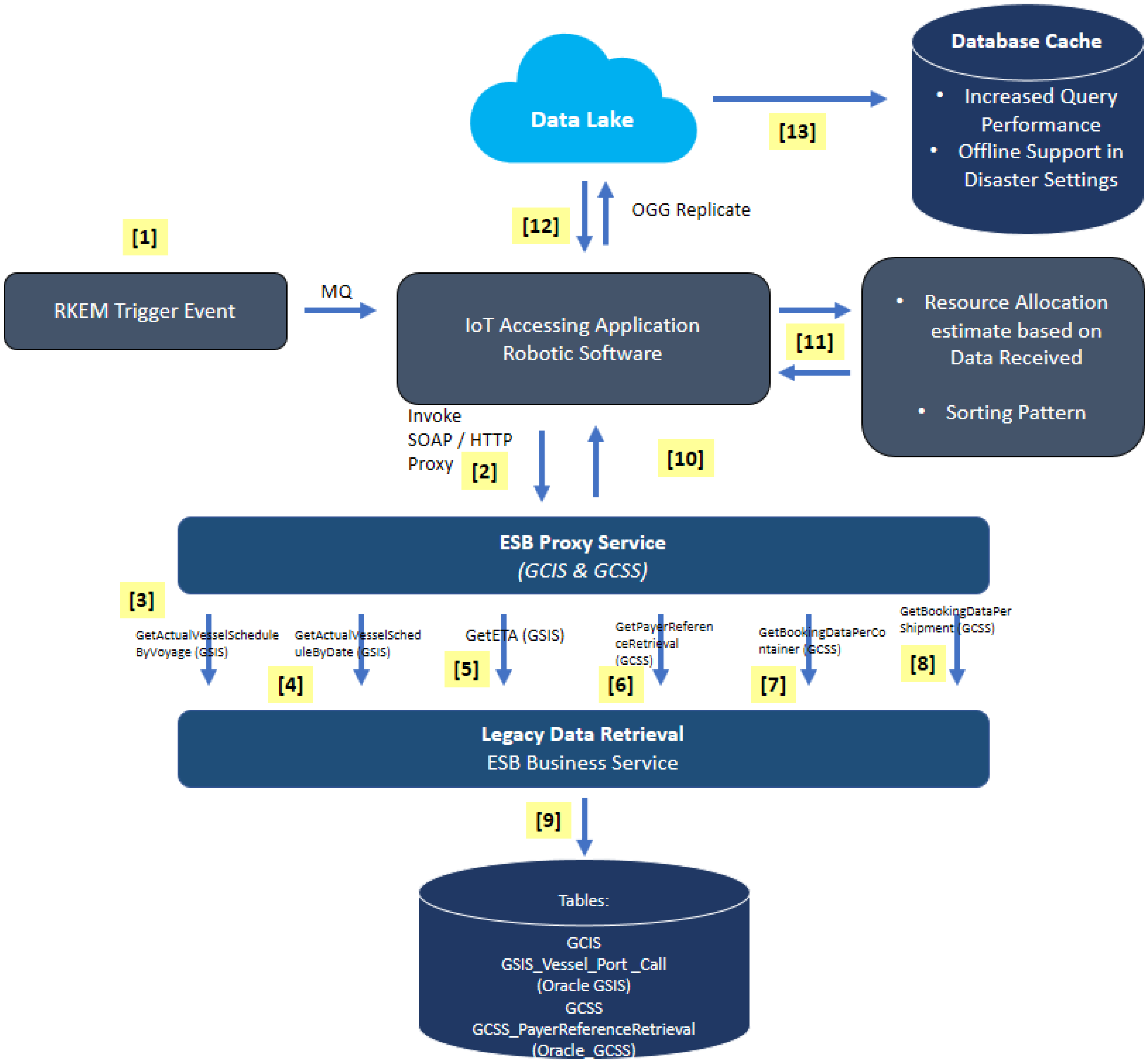


Figure 12. *Software Robotics Architectural Diagram*

Point 1 in the architectural diagram illustrates the RKEM Event that is being triggered two hours prior to the vessel will berth. The event will be placed on a message Queue (MQ), MQs are an asynchronous communication protocol, this means that the sender (RKEM) and the receiver (Robotic Software) do not need to interact within the transmitted message at the same time. RKEM will place the trigger on the queue, and the Robotic Software can pick it up once permitted. ***Point 2*** depicts the call that is being made from the robotics software to the GSIS and GCSS webservices. The Robotic Software will invoke the Enterprise Service Bus (ESB) proxy, through a Simple Object Access Protocol (SOAP). SOAP is a messaging protocol used for exchange of structured information between web services and computer networks. The SOAP message will hold a *VesselReferenceNumber* which is part of the RKEM event payload. ESB is a middleware technology that allow different web services to communicate with one another. ESB can be perceived as a contract agreement between two web services. ESB enable different web services and applications to communicate and understand each other, by enabling a common ground of understanding between applications, a simplified illustration is given below:

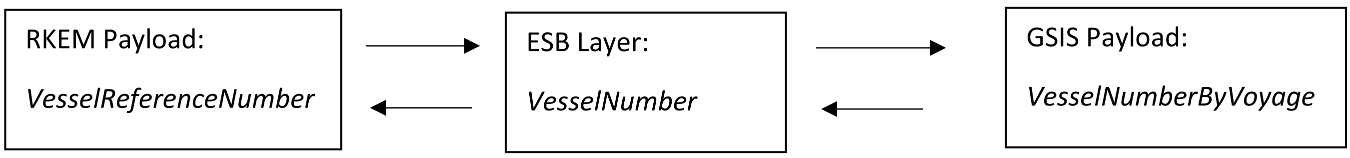


Figure 13. *Enterprise Service Bus Illustration*

To elaborate to ensure the understanding has been conveyed; above means that ESB has a common element that can re-used throughout the Service Oriented Architecture (SOA) landscape consisting of webservices. Hence, all webservices are enabled to communicate with one another as long as their webservice element are mapped to the ESB layers perception of that given data element. In the illustrated example, the RKEM payload holds the *VesselReferenceNumber*, this reference number is mapped to *VesselNumber* at the ESB layer, which in turn is mapped to *VesselNumberByVoyage* in GSIS. The ESB layer gives a unique possibility for re-usability and connections across a distributed system landscape, not limiting connection based on the original code elements. **Point 3, 4** and **5** depicts the ESB calls for each of the outlined services, these three calls are made to GSIS to understand which vessel that is incoming and it will hold the exact timestamp of estimate time of arrival. **Point 6, 7** and **9** depicts the ESB calls for each of the outlined GCSS services, based on the vessel details received from GSIS, GCSS will provide the data for which container bookings that are part of the specified vessel. Based on the booking data the Robotic Software will understand which containers that has to be unloaded from the vessel once it reaches the port. **Point 9,** depicts the fetch of data elements from the legacy relational database. **Point 10** depicts the response from GSIS and GCSS data back to the central Software Robotics component. **Point 11,** depicts how the Robotic Software based on the information retrieved from GSIS and GCSS will start resource estimations and plan for the allocation ahead of real-time ensuring that the most efficient unload route is achieved. Furthermore, the software robot will input data about last free days and expected pick-up dates to the reach stackers for them to start the planning pattern around which section of the container yard it most efficiently should be placed and stored. This is done by using a Quick Sort algorithm, to elaborate on this see below step by step example of a sorting scenario for eight containers:

Step 1, software robot compares today's date with the expected pick-up date for the specific container. *Step 2,* based on this comparison the software robot will get a numeric value of the number of days until expected pick-up. *Step 3,* in below dataset example *Today's date* is equal to 15-05-2018, based on this the *number of days until pick-up* the software robot will do a Quick Sort. *Step 4*, once the quick sort has been completed the software robot will be able to group the container's. *Step 5,* based on this grouping the automated shuttle carrier's will know to which section of the container yard the container should be driven (see appendix for container yard division).

Dataset before Quick Sort

Container ID	**Expected Pick-up Date**	**Number of days until pick-up**
ABC456	19-05-2018	4
ABC891	22-05-2018	7
ABC345	18-05-2018	3
ABC234	17-05-2018	2
ABC678	20-05-2018	5
ABC789	21-05-2018	6
ABC912	29-05-2018	14
ABC123	16-05-2018	1

Dataset after Quick Sort

Container ID	**Expected Pick-up Date**	**Number of days until pick-up**	**Container Yard Section**
ABC123	16-05-2018	1	Section: 1
ABC234	17-05-2018	2	Section: 2

ABC345	18-05-2018	3	Section: 3
ABC456	19-05-2018	4	Section: 4
ABC678	20-05-2018	5	Section: 5
ABC789	21-05-2018	6	Section: 6
ABC891	22-05-2018	7	Section: 7
ABC912	29-05-2018	14	Section: Long-standing

Table 9 and 10. *QuickSort algorithm before and after*

Point 12, depicts the data replication that is done in real-time, from the Robotics Software's internal database servers to the cloud. This is done through Oracle Golden Gate data replication technology. **Point 13,** depicts how a subset of the data is cached, in order to ensure data retrieval performance and offline support in case of a disaster setting.

Based on above two analytical assessments, we have understood the proposed solution building blocks in a more granular detail, both the software robotics and the IoT building blocks. The overall solution will in the following analytical section be analyzed in the light of the Holistic Model, this is done in order to depict which technical IoT/Robotics components that derives organizational benefits.

Holistic Model

The Holistic Model presents a framework for how companies can be considered as content provider, in form of data. This data is in turn generating beneficial value for the organization. As mentioned throughout the theoretical framework, we have limited the view of the model only to focus on the company related benefits, hence excluding *people* and *public institutions.* We will walk through the framework in the following manner; *first,* we will outline the content and data that is being generated and from which distinct usage scenarios the data will be generated from. *Secondly,* we will cover each of the five IoT traits, as presented by Uckelmann and further outline how each of these IoT traits are generating organizational value and benefits for APMT and ML.

Company content provided

The data that are being generated in the terminals while the vessel is docked is based on **GPS data**, which in real-time will feed the robotic software with location and position data of the specific container. In addition to GPS data extra **sensor data** are enabled on all physical digitized assets, these are used as an enabler for the M2M interactions that happens throughout the containers life cycle from; pre-berth until it has been stored in the container yard. Furthermore, there are data that is being generated outside of the terminals as depicted in below analysis of the robotic software, this data resides in **legacy systems** and is used as a foundation for the decision making that the robotic software will be enabled to do. This data is not generated through IoT components itself, but is a complementary asset for the solution to function properly, hence we included to mention it here in this section as a content provider for the overall IoT solution.

Internet of Things components and its organizational benefits

The five traits as presented by Uckelmann are; *Business Innovation, New Services Enabled by the Internet of Things, Front-end Internet of Things Architecture, Edge Devices and Management of Resources* and *back-end Internet of Things core architecture.*

Business Innovation, as uncovered throughout the above analysis we have clearly identified how the internal procedures for ML and APMT are being innovated in order to uncover else unseen organizational benefits. Throughout the financial analysis we identified extensive operational cost savings by fully automating the operational procedures in Terminals (85% savings). This saving takes basis in reduced run costs as well as an assumed 30% time saving based upon optimizations on; QC operation, Crane Truck alignment operations and Reach Stacking optimizations. *New Services Enabled by the Internet of Things,* as also uncovered throughout our analysis – a data driven operational process will establish transparencies. This can be considered as new services for the managerial layer of the organization, enabling benefits that concern with continuous learning and constant on-going improvements of the terminal operations. Furthermore, a fully GPS enabled container fleet will enable ML and APMT to have full visibility of their container network, which in turn will enable to distribute their container's more efficiently. Finally, new services will be enabled for competing shipping liners and carriers, as they will be enabled to partake in ML and APMTs extensive IoT infrastructure through sensor and GPS enablement of their own container fleets – this is to be further elaborated upon in the discussion section of this paper. *Front-end internet of things architecture,* as depicted throughout the architectural diagrams in the technical analysis there are two front-end entry points to the IoT domain. One front-end constituted of the user interface, which operators can access at the terminal site, in order to query a physical asset to execute (e.g. when a customer comes to pick-up a container). Another front-end capability is the Business Intelligence query interface layer that resides upon the data lake, this will allow the managerial layer in obtaining insights in the Terminals operations. *Edge devices and management of resources,* as outlined in the architectural analysis of the software robot, the connection to the legacy system domain is the edge device connection in the proposed solution. APMT and ML achieve benefits from connecting the two domains of system, as the input from the legacy domain will provide the required data for the robotics software to manage and control the allocation of resources (physical digitized assets). *Back-end Internet of Things Core Architecture,* the architectural core has been outlined in the above two analytical sections (first; IoT, second; robotic software). The core architecture set the foundation for how value is being obtained and how this in turn will drive organizational benefits. Above analytical assessment helped us summarize the overall benefits that that APMT and ML can expect through the deployment of the proposed solution.

Discussion

Solving the problem?

The first section of our discussion section will emphasize focus upon the general discussion points that we have noted and identified throughout the research and writing of this thesis. The second section of our discussion will take its outset in the technological discussion points that we have identified. The overarching goal of this thesis was to identify the current problems that are causing decreased performance in the discharge activities in Aarhus Havn. *The problem statements are assessed and discussed below in the light that the thesis would hypothetically implemented with the benefits that we have identified.* The *first* problem statement identified was the *communication gaps* existing in the terminal operations, as well as the communication with the operators on the vessel. In the proposed solution, the communication flows between autonomous operating entities are all automatic. Hence, we will argue that we have adequately spanned across this problem. However, as we have conducted our analysis in the pre-planning phase, it should be mentioned that we have been limited in doing actual operational test of data flows in the system, hence we have not been able to fully validate whether the perceived benefits would be achieved. But the solution building blocks exist and have been identified and on that basis, we consider the answer's provided related to this problem statement as sufficient. The *second* problem statements we sought to find a resolution to was an overall optimization of the QCs ability to unload and discharge containers in a more effective manner. Alexandru Duca raised a concern that fully automated autonomous QCs currently doesn't exist in the market. The reason provided by Alexandru was that he believed that humans are better at adapting to movements of the ship in the dock, the slack in the sway chains lifting the container, container weight points and other environmental conditions. However, as identified in below technological discussion we trust that we will provide the required technological ability to perform the unload activities from fully automated QCs. Based on the hypotheses that this technological setup will function as perceived, we consider the second problem statement as resolved, this is due to the fast-technological development and we do trust that there exist technologies that could solution the concerns brought up by Alexandru Duca. The *third* problem statement that we set out to resolve was with regards to the vast amounts of incidents that happen specifically at the quay side. We consider that the solution has successfully spanned across this issue, as there would be very limited human intervention in the actual operational procedures and hence less risk that these few operators would end up in an incident. The *fourth* problem statement that we sought to resolve as part of the solution was the issues existing around container sorting in the container yards. The sorting algorithm presented in the technical section of our analysis will ensure that the Reach Stackers are enabled in informed decision making enabled to place the container in the most efficient container yard section. Based on expected pick up date and the structured container yard sections. On this argument, we consider this problem statement to be resolve. The *fifth* problem statement that we identified was that there are wastes related to truck and crane alignment. Furthermore, we identified how conemen are manually assisting in the alignment procedures between the QCs and automated Shuttle Carriers, an incident prone activity. As the alignment between QC and Automated Shuttle Carriers would be done in a M2M setting, there are no risks involved. Our assumption is that the alignment would be done with adequate efficiency between the two machines (and based on GPS and sensor data), hence we also consider that the proposed solution will resolve this issue, in a two-fold manner (efficiency and risk reduction). The *sixth* problem statement that Alexandru Duca helped us identify was APMTs current ability, or lack of the same, to drive data driven performance improvements. As most of the physical assets does not currently generate data it is difficult for management to get a bird eye view of why a specific terminal is performing relatively worse than another terminal. By having QCs, Shuttle Carriers and Reach Stackers fully automated management are enabled in data-driven decision making and get more transparency on the operational procedures, hence enabling them in continuous learning – and ultimately operational excellence. One could argue that continuous learning elements should also be integrated in the IoT enabled assets through artificial intelligence (AI), meaning that no human intervention would be required in order for the automated assets to operate more efficiently. With AI and machine learning, management interference would be negligible as the assets would be able to perform their own decision-making to align with the critical path of efficiency. The *seventh* and last problem statement that we set out to resolve was the operating variances that especially exists within the QC operations (Alexandru Duca, 2018), by having the QC, Shuttle Carrier and Reach Stacker operation fully automated there would not exist any operator variance as the operation would consist of identical technological elements. This will ensure a tangible average of performance enabling management to forecast performance and turnover times (of vessels) in far greater detail and with better precision.

Above we have understood that each of the seven problem statements will potentially be resolved with the solution that is being presented as part of this thesis. However, as mentioned above; the reader must note that none of the elements of the solution have been rolled out in a real-life setting and hence we have not been able to evidently proof that the solution in fact would resolve each of these problem statements. The tradeoff in research settings that are cutting edge in terms of industry development is that there may exist limitations in terms of available data and evidence. This have turned out to be a limitation for our ability to establish a foundational evidence that we would drive efficiency and operational excellence with the proposed solution. However, we are confident and trust that we have established findings that can function as a springboard for potential future development of the same solution, or similar solution.

Synergies

Another point that we set out to achieve was that we wanted to drive further benefits on the synergies that we assumed would exist between the two business units, APMT and ML. The synergies that we sought to identify and drive value from, was to connect the ML legacy system landscape with APMTs operational system landscape in the terminals. Through the interviews with Alexandru Duca he shed light upon how APMT currently is sourcing data from the ML legacy systems. The data is being transferred through different Electronic Data Interchange (EDI) connections and value is currently already being derived from this data. However, Alexandru Duca mentioned that each of the EDIs have different connections because the systems used in each terminal differs from terminal to terminal. Hence, he mentioned that an interesting area to focus on in the future is to align systems across all APMT owned terminals in order to standardize how the terminals are being operated from a systems point of view. This is also a critical point for our proposed solution, as it would be easier to scale if the systems that it has to connect with are generic across all terminals. Enabling us to make one generic solution that can be scaled across, instead of having IoT/Robotics solutions tailored specifically to each terminal. Hence, to some extent we failed to achieve further synergies between the two business units, but simultaneously we identified a potential blocker for leveraging on the synergies between the two units effectively.

Import Cycle Only

During the conducted interview sessions and correspondences with Alexandru Duca he brought to our attention that in an actual implementation setting, it would be unlikely only to focus on automation of the import cycle. This is due to the fact that unload and load of containers rarely happens in isolation, meaning that in a real life setting one would have to assess both the import, export cycle and ship-to-ship procedures. We decided to focus on the import cycle to allow ourselves to go into more granular details around the solution, and with the events happening to a container from pre-berth until the container has been placed in the container yard for storage. The hardware and the structural components for the import cycle are identical to those required to support the export cycle. The only difference as identified by Alexandru Duca is that the procedures would happen in reversed order as compared to the import cycle.

Technological Discussion

Throughout our paper we have made some technological assumptions that we in this section would like to look at critically to see how it will apply to the real-world scenarios in the terminal operations. In our paper, we base the unloading and alignment of shuttle carriers / cranes based on GPS signals on the containers and in the Terminal equipment. In reality GPS sensors are not a 100% precise but have a variance of 1-2 meters which makes it impossible for a crane to have a 100% accuracy when it comes to lifting the containers. To compensate for this lack of precision in GPS technology we would in reality need extra equipment such as cameras mounted on the crane arms to live stream a video image and use image recognition to get a more precise location of the container and thereby enabling a more accurate pickup of containers. Another factor that makes it hard for the robotic cranes to be a 100% accurate is the fact that when the vessel is tied to the dock it still constantly moves a bit, but with the camera solution just described, the cranes will be able to adjust to that and counter the movement of the ship and pick the container up accurately. This will be done by writing some code that moves the crane so that the container is constantly in the center of the camera image, so if the container moved half a meter to the left the camera/GPS sees it and tells the crane to move half a meter to the left as well. You could even install underwater sensors in the docking area that tells the software robot how the stream in the dock is and calculate in which direction the ship will move. Even though we have not described this in our solution as we make the assumption that the GPS signals are accurate, it is taken into account in the Financial Appraisal in the Business Case as the cost estimates are based on a fully automated project in Port Los Angeles where they are also going to face the same issue with unprecise GPS signals. Lastly, we would like to mention that the reason we have chosen to make the assumption of GPS signals being precise is because the IoT market is evolving so fast that it is a real possibility that the GPS sensors will be close to a 100% precise at the time this project would be launched.

Next in the technological Limitations we would like to talk about the fact that we in our solution start to calculate unloading routes at the Berth Event but in reality, we could start this event much earlier if all terminals were automated with our solution for Aarhus Havn. If that was the case we could get the data of where all containers are located as the ships takes off from the previous port. This is due to the fact that the containers do not move around after leaving the Terminal, so we could already read the sensor data from the containers and see how they are places in regards to each other and in that way already calculate the best unloading route based on container IDs.

The last Technological Limitation we would like to discuss is the fact that we talk about automating all the Terminal operating assets but we do not talk about automated vessels. This is due to recent statement from the CEO Søren Skou, who said at an interview with Bloomberg that he does not see in the foreseeable future that is will be realistic that container ships that sail with thousands of containers will be allowed to sail autonomously without any humans operating the ship.

"Even if the technology advances, I don't expect we will be allowed to sail around with 400-meter long container ships, weighing 200,000 tonnes without any human beings on board," the 53-year-old CEO said. "I don't think it will be a driver of efficiency, not in my time." – Søren Skou (Bloomberg, 2018)

Going beyond Maersk

Our solution is completely focused on automating Maersk's terminal in Aarhus as Maersk is the company we have chosen to write our thesis around, but our solution could be sold as a service to other terminals across the globe. It would also be possible to sell part of our solution as services, such as the installation of GPS sensors in containers, Automated Shuttle Carriers, Automated Quay Cranes, Automated Reach Stackers and a Software robot that's reads data from a data repository and have an interface to control/monitor terminal operations. This option would be able to generate additional revenue for Maersk but might however help competitors to grow and have a better technological foundation to start to scale operations and take away operations from Maersk terminals.

Estimated Cost

The cost structure that we introduce in the financial Appraisal as part of the business case is purely based on estimates from other players in the terminal industry and on our own estimates on salary costs and minimal number of operators needed to operate the terminal. This can be criticized as it might not give a realistic picture of what the current/future operating costs will be from this solution. However, we do not have the insights to make our own estimate of what is needed to fully automate the terminal machinery and we are not allowed to use internal salary costs for material shared outside the organization which have made it impossible for us to give a precise picture of the solution's cost structure. Alternatively we could have looked into the costs of building the Maasvlakte II Terminal in Netherland but even with that information we would still have to make estimates as the Maasvlakte II Terminal is only partly automated and are still being operated with joysticks by humans from a local operating center in the terminal, so we would have had to estimate the additional cost of going from semi-automated to fully automated and as the hardware costs might have changed quite a bit since the Maasvlakte II project was initiated, we don't believe that that estimate would have been any closer than the estimate we have presented in our paper.

Reflection

In this section, we intend to reflect upon the learning questions that have been presented throughout the two courses we have decided to found our thesis upon; Internet of Things and Robot Armada. Theories from both courses have been used in interdisciplinarity to uncover how IoT and robotics are two complementary research fields. Once we have reflected upon the two courses, we evaluate our, research and findings against the overarching learning objectives that constitutes a successful Master of Science thesis.

Internet of Things

From the *Internet of Things* course the ***first*** learning objective was to; *Understand the main concepts, models and frameworks of the Internet of Things and its impact for business innovation.* Throughout this thesis we have successfully applied the two main models that was presented throughout the course (EPCglobal Future Architecture Model and Holistic Model). Furthermore, we have proposed a mixture of an IoT and robotics solution that will drive innovation and derive business benefits for the targeted organizations. The ***second*** learning objective was; *Be familiar with the tools and technologies (Sensors, RFID, Embedded Systems) required to create new business solutions.* An integral part of the proposed solution in this thesis is IoT devices e.g. Sensors and GPS streaming technologies, furthermore we have achieved to propose an architecture for the embedded software system that connects directly with the IoT domain. The ***third*** learning objective was; *Analyze, using different frameworks, the Internet of Things; strategic implications, user centered design and technical challenges related to form and function.* We have successfully used different frameworks to analyze and understand the strategic implications the proposed solution would have for APMT and ML. These strategic implications should be seen in the light of the identified problem statements and how we uncovered the solution would be resolve and benefit the same areas. The MUST framework helped us understand a method for ensuring a user centered design. The technical analysis shed light upon the technicalities of the proposed solution, and how GPS (not accurate enough) and QC digitization (currently non-existent) may be blockers to the proposed solution. The ***fourth*** learning objective was; *Critically evaluate ethical, privacy, and security issues related to the Internet of Things.* We are both aware of the aspects that fall with regards to ethics, privacy and security, however we were afraid to blur our focus and make our scope too wide. Hence, it was an intended decision to limit the thesis from these points and solely focus on the solution. It would have been interesting to analyze these areas however, especially since the shipping industry is conservative in nature, one could imagine push-back from such solution, which is being presented. The ***fifth*** and final learning objective of the Internet of Things course was; *Design/Develop parts of an Internet of Things solution to create business value.* As mentioned several throughout this thesis, we have been unable to develop any of the actual building blocks of the proposed solution, however we trust that we have sufficiently depicted how the architectural design could be structured for this IoT solution. To summarize on above learning objectives, we are confident that we have adequately touched upon each of them.

Robot Armada

From the Robot Armada course, the ***First*** learning objective was; *Be able to assess and discuss business strengths and weaknesses of Robots.* We are confident that we have achieved to showcase the business strengths that can be generated through the appliance of robotics, both software -and physical robotics (based on resolution of problem statements). Furthermore, we uncovered financial savings in the operational run costs and a 30% increase in efficiency. To the financial section of this paper, however; we need to stress that most of the figures are based on assumptions and research of secondary data. The costs and the uncertainty on ability to materialize on the investment, however we would consider a weakness of the proposed solution. The ***second*** learning objective presented through the course was; *Can account for how productivity problems, capacity challenges and lack of innovation can be solved by use of robots.* The identified problem statements and the resolution for the same, as well as the additional organizational benefits uncovered we are confident that we have showcased and accounted for how productivity, problems and lack of innovation will be catered for with the introduction of the proposed solution. The ***third*** learning objective was; *understand differences and be able to exemplify industry, service, social, and software robots.* Throughout this thesis we have made a clear distinction between the software robotics and the digitization of physical assets. In this paper, the digitization of physical assets has been considered as IoT elements, they might as well have referred as industrial robots – hence we consider that we have sufficiently touched upon this learning objective. The ***fourth*** learning objective was; *Can give examples of and discuss management challenges when implementing robots in industrial settings.* The original intention of this thesis was to uncover the managerial challenges related to such implementation - as the proposed solution. However, the focus in this thesis resides on the design and organizational benefits that can be achieved. Considerations and data for the roll-out phase of the solution was difficult to achieve, as the organization is currently not close to have fully automated operational procedures. Hence, we have had to neglect this are of focus in this thesis – with regret. The ***fifth*** learning objective was; *Can account for the industrial age management mindset and the innovation management perspectives and are able to apply adoption of robots.* We have uncovered how robotics and IoT is tied to the third wave of IT-driven competition and how Web 3.0 will be an enabler for the same. Furthermore, we have understood through the appliance of the Holistic model how the solution is driving organizational innovation. To summarize on above learning objectives, we are confident that have sufficiently touched upon each of them, apart from the fourth objective. This has been neglected due to difficulties obtaining the required and relevant data to analyze and present the same.

Master Thesis Learning Objectives

Throughout the research, analysis and writing of this thesis we have used the learning objectives presented in the course description as a guideline. The reason for tying our writing closely to these learning objectives is to ensure that we were aligned with the requirements expected. The ***first*** learning objective is; *The thesis is governed by a student-developed problem statement which is relevant to the programme.* We have thoroughly developed problem statements that we sought to resolve throughout this thesis, furthermore we have developed a research question, that constitutes the overarching problem statements. The ***second*** problem statement is; *the thesis is delimited to the effect that its analyses and discussions are relevant, necessary and adequate to answer the problem.* We are confident that we have narrowed our focus sufficiently, without compromising coverage. Furthermore, we trust that our analysis and discussion are relevant, both seen in light of the proposed solution and in light of the problem statements that the proposed solution resolves. The ***third*** learning objective is; *The thesis contains a discussion of and reason for the choice and omissions with respect to subject delimitation, theories, methodology and empirics.* In the *theoretical framework* section of this paper, we justify why theories have been included, as well as why some components of theories have been excluded. Furthermore, we have clearly stated the research limitations that we have faced, clearly outlining for the reader why some sections have been excluded and why some sections have been based on assumptions. The ***fourth*** learning objective is; *the thesis provided critical reflection on the selected theories, methodology and empirics and assesses their applicability in answering the problem statement.* The business analysis sets the foundation, as to whether there is financial incentive build the proposed solution (there is). Whereas the technical section is constituted by three technical frameworks, which all support the design and architecture of the proposed solution. The proposed solution is the answer to the identified problem statements; hence we consider us having achieved this learning objective. The ***fifth*** learning objective is; *The thesis is consistent to the effect that the choice and application of theories and empirics interact and complement the production of knowledge.* We are confident about the coherency that this thesis achieves on basis of the applied theories and the problem statements that we initially set out to resolve. The ***sixth*** learning objective is; *Allegations made in the analysis and conclusion are documented.* We trust that we have argued on allegations, either through primary or secondary data. The ***seventh*** learning objective is; *The analysis includes deliberations on the degree to which the results of the thesis resemble and/or deviate from other similar surveys in the field.* We have not been able to achieve this. Currently there are a lot of operators that are striving to establish a 'fully automated' terminal, and some terminals consider themselves as successful in this endeavor. However, there is a misalignment in what is being perceived as fully automated, the terminal's that consider them fully automated are not autonomous, they are 'just' controlled remotely from a control tower. Hence, we have not been able to find academia or internal knowledge within the Maersk domain that could validate or reject whether we have deviated from other similar researches. The automation that we seek to achieve is fully automated – autonomously controlled. The ***eighth*** learning objective is; *the analysis focuses on a delimited problem i.e. provides an in-depth analysis.* We trust that are area of focus have been focused to the extent that it answers the problem statements identified during our research (see; discussion section). One could argue that we could have achieved a more in-depth analysis of the technical architecture, however we are satisfied with the core building blocks that we have established based on the theories available from the chosen courses. The ***ninth*** learning objective is; *The thesis discusses the premises of the theories and the impact of those premises on knowledge that can be created.* And get we would like to stress that we have justified and guided the reader through why the theories have been chosen and applied as they have, hence we consider we have adequately addressed this learning objective. The ***tenth*** and final learning objective is; *The thesis contributes to a new perspective, e.g. by applying a known theory on previously unexamined empirics.* We have applied already existing theories from the mentioned courses, to approach an existing problem. The approach and the overarching goal of a fully automated (and autonomous) end to end process has not been achieved, but the theories have been used as supporting elements to analyze and find a potential architecture that could ensure full autonomy.

As an overall summary to the above reflection, we are confident that we have followed and adequately touched upon each of the raised learning objectives. Some have been addressed better than others, the reason for this is that we have faced constraints in terms of available data. It is exciting to write on a subject that are cutting-edge in nature, however it can be a pitfall as well, as there are data and components that are not easily accessible. Considering these factors, we are satisfied with the overall product that we have achieved to write. We trust that this can be used as a springboard for ML and APMT, having done a vast part of the analysis and though management. We are aware that this is a bold aspiration, but the writing of this thesis has brought attention towards the combination of Robotics software and IoT capabilities at the highest levels of the organization.

Conclusion

The overarching goal we sought to achieve through this empirical research paper was to identify how AP Moller Terminals and Maersk Line could achieve organizational benefits through the deployment of Internet of Things and Robotic software capabilities in Aarhus Havn. Our interest in these research areas were founded in the *seven* problem statements that we identified throughout our research and analysis of the current organizational settings. This thesis brings the reader through two different, yet complementing, focus areas. The first being an assessment of the business case and financial contextualities for the solution that is being proposed. And secondly, a technical assessment of the design process, Internet of Things architecture and the software robotics architecture. To support our research and findings within the business domain, we applied a generic business case. This made us understand the organizational benefits and shed light upon tangible improvements. Both in terms of a 30% increase in the operational terminal throughput and in terms of operational run cost savings of 85%. Based on these numbers we were enabled to formulate a cost/benefit analysis, which ultimately helped us establish a justification for why the proposed solution should be taken forward by the managerial layer in both AP Moller Terminals and Maersk Line. In the last section of the business analysis we applied a Business Canvas Model. This was applied to establish a holistic view of the involved parties and to have a presentable one-pager of the business model for AP Moller Terminals -and Maersk Line management.

The technical analysis in this thesis has been divided into four sections. In the first part of the analysis we applied the MUST framework. Through this framework we understood the importance of including both IT professionals and a Steering Committee in a joint effort throughout the on-going design activities. By doing so, we concluded how to achieve and ensure better alignment between business requirements and what is being developed. The MUST framework also defined how designing in smaller iterations was key in order to align with e.g. dynamically changing business requirements. This ties together with the identified *project approach* that we uncovered during the business analysis – namely delivering the software part of the project by following an agile methodology. In the second part of the technical analysis we applied the EPCglobal framework. We applied this as a generic framework for the reader to understand the pre-requisites and the technical building blocks that constitutes an IoT solution. In addition to this we outlined how each of the building blocks would be applied and function in our proposed solution. One of the building blocks for the IoT architecture is its integration with edge architecture – namely the software robot. The software robot component was analyzed throughout the third section of the technical analysis. We strove to outline a granular technical design of how the software robot would function in terms of data enrichment, resource allocation and sorting. With the overarching goal to depict how the legacy landscape would complement the Internet of Things enabled architecture. We identified that AP Moller Terminals to some extent is already subscribing to these data feeds (from Maersk Line), however there is not an existing global standard for transmitting this data, causing unnecessary system tailorization from terminal to terminal. Concluding that the proposed solution would enhance the already existing synergies further, by enabling a standardized generic architecture that can be implemented globally across all terminals, with outset in Aarhus Havn. In the fourth and final section of the technical analysis we applied the Holistic Model in order to understand how content (in the form of data) is being generated and which IoT traits that are used to generate organizational value. The value analysis is based both on the IoT and robotic software solution as these two as these two solutions would not work in isolation from one another.

As stated in the introductory part of this thesis our intention was to uncover:

How can AP Moller Terminals and Maersk Line derive value from software robotics and a digitized terminal infrastructure in Aarhus Havn?

On basis of the above mentioned analytical findings we would conclude that AP Moller Terminals and Maersk Line gain significantly value from automating the Aarhus Havn's terminal. both in terms of in enriched technological landscape that will enable better data driven decision making and in terms of getting a more productive and cost-efficient terminal.

Litterature

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Appendix

Appendix 1

Year	Cost	Benefit	Acc Cost	Acc Benefits
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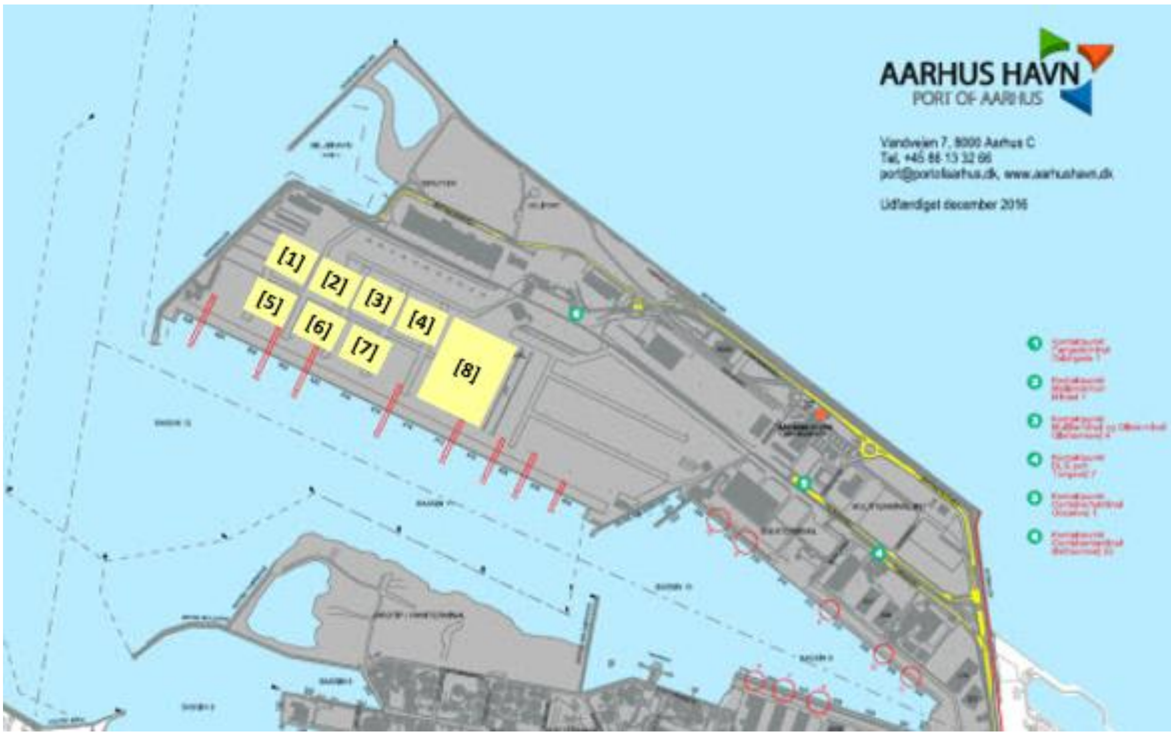
4	4.550.400	51.465.600	648.201.600	205862400
5	4.550.400	51.465.600	652.752.000	257328000
6	4.550.400	51.465.600	657.302.400	308793600
7	4.550.400	51.465.600	661.852.800	360259200
8	4.550.400	51.465.600	666.403.200	411724800
9	4.550.400	51.465.600	670.953.600	463190400
10	4.550.400	51.465.600	675.504.000	514656000
11	4.550.400	51.465.600	680.054.400	566121600
12	4.550.400	51.465.600	684.604.800	617587200
13	4.550.400	51.465.600	689.155.200	669052800
14	4.550.400	51.465.600	693.705.600	720518400
15	4.550.400	51.465.600	698.256.000	771984000

Appendix 2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PORT OF AARHUS
Vandvejen 7, 8000 Aarhus C
Udfærdiget december 2016
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Appendix 3

Transcript from Interview with Alexandru Duca

[Henrik]

Hallo Alexandru, Henrik here and I have Jakob with me in the room

[Alexandru]

Hi Henrik, Hi Jakob, how are you?

[Henrik]

We are both fine, thank you. How are you?

[Alexandru]

Long day at the office but I am good thank you.

[Jakob]

Good. To start with, can you please state your position? We know your position but for the sake of the interview we would like to just say a couple of words about your position

[Alexandru]

Okay Sure, I am Alexandru Duca and I am head of APMT.

[Henrik]

Thank you. So let's jump right into it, we would like to start out with discussing some of the points you mentioned in your email. You mention that there is already an integrated process of coordinating between terminals, what kind of integration are we talking about?

[Alexandru]

So, currently the way things work is that the terminals register what containers have been unloaded to a ship and then we have a terminal operations center that handle that information and send a discharge list to each terminal on the ships route to let them know what containers needs to be taken off.

[Jakob]

Alright, next in your email, you mention that you don't see Quay Cranes being able to be automated in the near future. Could you please elaborate a bit on that?

[Alexandru]

The reason for this is that the Quay crane cannot be automatically unload containers from the ship as the ship is always moving even when in harbor. People have adaptability to adjust to the moving containers and pick them up in a consistent manner and we don't see a computer being able to take all of those movements into account. Furthermore in terminal operations we always prefer the consistent option compared to a software that will operate inconsistently depending on how many movements are going on with the ship.

[Jakob]

With enough sensors installed on the crane wouldn't it be able to take in to account all of these movement and counter them when picking up the container?

[Alexandru]

I think there is too many variables for it to handle as there is also slack in the chains that are lifting up the container that also needs to be taken into account when aligning the crane with the container.

[Henrik]

Okay, lets move on. The point we would like to discuss is the point about waste buckets in the terminal operations.

[Alexandru]

Yes, in APMT we devide our waste buckets into either a stock problem or a flow problem were the flow problem is regarding all the hardware such as Cranes, Shuttle Carriers, QCs etc. and stock problems is about the storing of the containers. We do however have a problem with capturing all waste buckets as much of the operation is done with humans which is hard to get many measurements from compared to robots.

[Jakob]

What is your main waste buckets in APMT?

[Alexandru]

The biggest waste bucket is that we don’t know what and how big all the waste buckets are as we don’t have any data on it, due to the fact that large parts of operation is done by humans, but apart from this one I would say Waiting time like QCs waitng for Shuttle Carriers. Alignment smallest equipment needs to align to the bigger. Operator variance people operate in different ways, good at some tings and bad at some. Peter might be really good at unloading and Frank might be very good at loading.

[Henrik]

Okay great thank you. How do you see the digital evolution in APMT?

[Alexandru]

The terminal industry is a very conservative industry so many people prefer to run operation as they always have done, so the technological advancement is going a bit slow. Personally I see plenty of opportunities for improvements in terms of putting more technology into our cranes in the terminal.

[Jakob]

Thanks a lot Alexandru, I can see that our time is up, so thanks a lot for taking your time to talk to us and I hope that it is okay that we might send you a couple of follow up questions afterwards.

[Alexandru]

Yes sure, and no problem guys, I am happy to help.

[Henrik]

Thanks a lot Alexsandru. Have a great day. Goodbye.

[Alexandru]

Goodbye.

Appendix 4

APM Terminal Introduction

Slide 1

Slide 2

This presentation will provide a brief introduction to the world of shipping, global trade and economic development; the world of APM Terminals.

Slide 3

APM Terminals operates a Global Terminal Network which includes 20,600 personnel in 60 countries, and was named "Port Operator of the Year" at the Lloyd's List 2015 Global Awards.

We manage or have interests in 73 operating port facilities, including container, oil and general cargo terminals in 40 countries

8 new terminal projects now in development at Abidjan, Ivory

Coast; Izmir, Turkey; Vado, Italy; Moin, Costa Rica; Lazaro Cardenas, Mexico; Ningbo, China; Tema, Ghana and Puerto Quetzal, Guatemala.

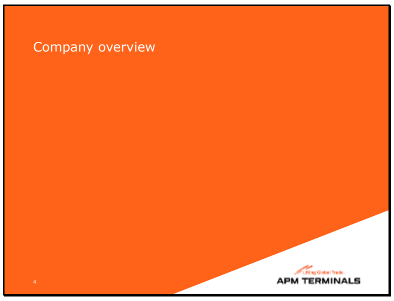
16 expansions or upgrades of existing facilities are underway, including Apapa, and Onne Nigeria, Poti, Georgia; Callao, Peru; Qingdao, China; Gothenburg, Sweden; and Pipavav, India.

APM Terminals Inland Services is a major presence in global logistics with 143 operations in 39 countries. In a global market of 679 million container twenty-foot equivalent units, or "TEUs" loaded and discharged at ports around the world in 2014, APM Terminals' container lifting was 38.3 million, weighted by our equity share in the port and terminal facilities.

APM Terminals ranked 3rd globally in container handling volume by this measure in 2014 (with a 5.5% market share), and second in terms of overall terminal network capacity, with 92.4 million TEUs (behind only Hutchison Port Holdings, with 102.1 million TEUs). [*Drewry Global Terminal Operators Annual Report 2015*]

Our revenue in 2014 was $4.45 billion dollars including both port and inland cargo and container services.

Slide 4



Slide 5

APM Terminals is a member of the Maersk Group which has headquarters in Copenhagen, Denmark, and was named "Port Operator of the Year" at the 2015 Lloyd's List Global Awards, in London.

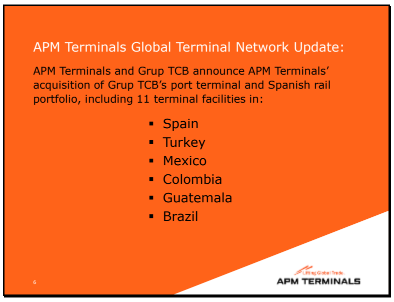
The Maersk Group, with overall revenue of $47.57 billion dollars in 2014, employs 89,000 people in 130 countries. APM Terminals is one of the Group's five primary business units, which also include *Maersk Line*, the world's largest shipping line, *Maersk Oil*, *Maersk Drilling* and *APM Shipping Services*.

The Maersk Group has a century of history in the shipping industry, beginning with the establishment of the original company in 1912 in Copenhagen by company founder Mr. A.P. Møller, who in partnership with his father had invested in a second-hand tramp steamer in 1904.

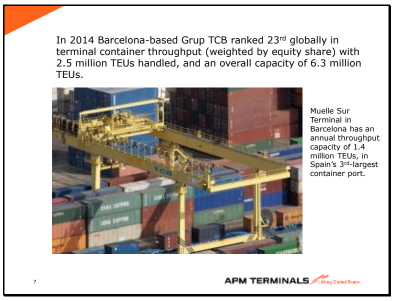
The first dedicated port facility under company operation was opened at the Brooklyn Piers, in the Port of New York in 1958.

A total of 12 facilities which are part of the APM Terminals Global Terminal Network were cited as among global and regional productivity leaders in 2014 by the Annual JOC Group Productivity Study. Retaining its status as the world's most productive container terminal, as measured by crane moves with a vessel alongside, was APM Terminals Yokohama, the 2013 leader as well, improving crane moves per hour (MPH) to 186, from the world-leading 180 MPH measured by the JOC Study last year.

Slide 6



Slide 7

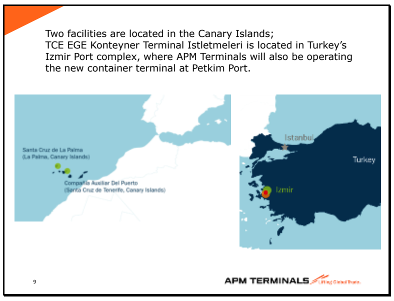


APM Terminals has completed the acquisition of Grup Maritim TCB, including its 11 container terminal portfolio and Spanish railroad operations, representing new capacity of 4.3 million TEUs with facilities in Spain, Turkey, Guatemala, Mexico, Colombia and Brazil. The transaction is expected to close by the end of the year and is subject to regulatory approval.

Slide 8

Grup Maritim TCB 's Spanish container terminal locations include Barcelona, Valencia and Castellon, on the Mediterranean coast, along with the concessions in Gijon, on the Bay of Biscay, and in the Canary Islands: Santa Cruz on Tenerife and La Palma on Gran Canaria. In addition to the existing APM Terminals Algeciras facility at Spain's largest container port, it is notable that the Spanish ports of Valencia and Barcelona, which rank 2nd and 3rd in Spain for container traffic, will now also be APM Terminals container facility locations. With the addition as well of the TCB terminals in Gijon, Castellon and the Canary Islands, APM Terminals will become one of the largest, if not the single largest terminal operator in Spain by capacity and volume.

Slide 9



Adding TCB's combined 1.77 million TEU Spanish throughput of 2014 to APM Terminals Algeciras' total creates an aggregate Spanish port volume of 5.3 million TEUs, or approximately slightly less than half of Spain's total annual container throughput.

Outside of Spain, Grup Maritim TCB's terminal operations include Izmir, Turkey; Yucatan, Mexico; Quetzal, Guatemala (under construction, opening 2016); Buenaventura, Colombia, on the Pacific Coast; and Paranagua, Brazil.

Slide 10

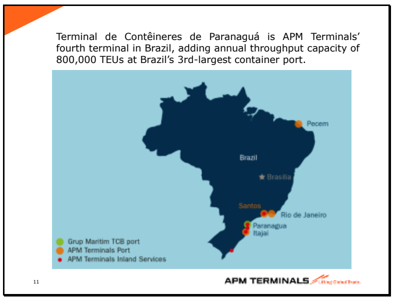
Terminal de Contenedores de Yucatán (TCY) in the Port of Progreso, is at present a relatively small facility, with an annual throughput capacity of 110,000 TEUs, and a 2014 throughput of 66,000 TEUs, accounting for all of the port's container traffic. APM Terminals Lazaro Cardenas will be opening on Mexico's west coast in 2016 with an annual throughout capacity of 1.2 million TEUs.

Currently still under construction, Terminal de Contenedores Quetzal, on Guatemala's Pacific Coast, will provide an annual container throughput capacity of 340,000 TEU when the facility becomes operational late in 2015.

Guatemalan ports handled a combined 1.26 million TEUs in 2014, trailing only Costa Rica with 1.29 million TEUs, and Panama, with its Canal-associated transshipment ports at Colon and Balboa, which handled 6.77 million TEUs in 2014, among the Central American nations. APM Terminals Moin, on Costa Rica's Atlantic coast, is scheduled to open in 2018 with an annual throughput capacity of 1.3 million TEUs.

Sociedad Portuaria Terminal de Contenedores de Buenaventura (TCBUEN) is a 500,000 annual TEU capacity facility at the Port of Buenaventura, Colombia's second-busiest container port, with a 2014 throughput of 855,000 TEUs, on northern South America's Pacific Coast. In August APM Terminals' obtained a 51% majority share in a new joint venture with Compas S.A. to operate a 250,000 TEU annual capacity terminal at the Port of Cartagena, Columbia's busiest container port, located on the Atlantic side of the Isthmus of Panama, at the top of northern South America.

Slide 11

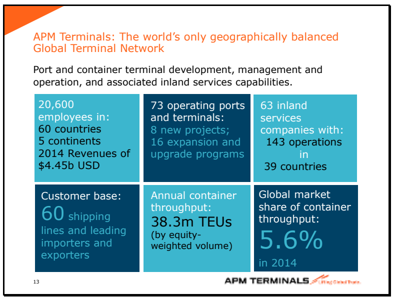


Terminal de Contêineres de Paranaguá (TCP), is located in Brazil's third-busiest container port, which handled 757,000 TEUs in 2014, trailing only Santos, South America's busiest container port, (3.04 million TEUs) and the Itajaí/Portonave port complex (1.04 million TEUs). TCP becomes APM Terminals' fourth operating facility in Brazil, including BTP (Santos), APM Terminals Itajaí and APM Terminals Pecém. Brazil's container throughput was 9.2 million TEUs in 2014, the highest total of any Latin American country.

Slide 12

TCB Intermodal, TMZ Stevedoring Services and TVC Railway Transport will become part of APM Terminals Inland Services, serving rail connections between Valencia and Barcelona, and northern and central Spanish industrial and population centers.

Slide 13



APM Terminals is the world's most geographically balanced global port, terminal and inland services network.

We invest, design, develop, implement, operate and manage container and multi-purpose ports - and inland cargo handling services.

Our market share of global container throughput, weighted by equity share, was 5.6% in 2014 of a total of 679 million TEUs handled worldwide. [*Drewry: August 2015*].

Slide 14

We are an industry leader in safety and sustainability.

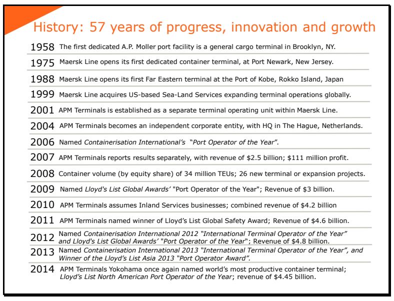
Our Lost-Time Injury Frequency Rate, measured in Lost-Time Injuries per million man-hours worked, declined by 22% in 2014 to 1.41 from 1.81.

Our company goal of sustainability is also progressing very successfully, through increased use of alternative environmentally friendly energy sources, and reduced carbon dioxide output per TEU handled.

Slide 15

We are proud to have combined the most talented and proactive international team of business leaders in the industry, each of whom represents significant experience in managing the complexities and opportunities of running and growing a global business.

Slide 16



APM Terminals can trace its heritage in port and terminal operations back more than half a century to the first A.P. Moller port terminal in Brooklyn, New York.

In 1975 Maersk Line opened its first dedicated container terminal, and became a major presence in global terminal operations and management.

In 1999 with Maersk Line's acquisition of US-based Sea-Land Service, we significantly enlarged our scope of terminals and operations.

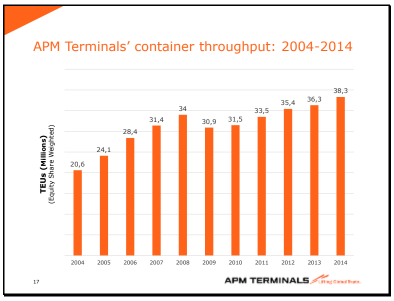
2001 marked the establishment of APM Terminals as a separate entity – serving Maersk Line's terminal needs.

As the company grew and diversified our client portfolio – the need to be more independent in our activities and more diversified in our business model became clear.

In 2004, APM Terminals was established as a separate and independent business unit within the Maersk Group and moved into our own world headquarters in The Hague, Netherlands.

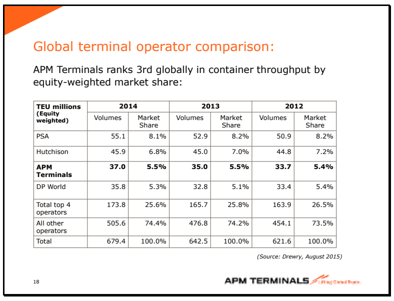
Today our clients include al of the world's major shipping lines, and the APM Terminals Global Terminal Network has been recognized for excellence and industry leadership in Safety, Productivity and Innovation.

Slide 17



APM Terminals' 2014 container volume growth of 5.5% matched global container volume growth to achieve a new company record of 38.3 million TEUs handled (weighted by equity share).

Slide 18



TEU millions (Equity weighted)	2014		2013		2012	
	Volumes	Market Share	Volumes	Market Share	Volumes	Market Share
PSA	55.1	8.1%	52.9	8.2%	50.9	8.2%
Hutchison	45.9	6.8%	45.0	7.0%	44.8	7.2%
APM Terminals	**37.0**	**5.5%**	**35.0**	**5.5%**	**33.7**	**5.4%**
DP World	35.8	5.3%	32.8	5.1%	33.4	5.4%
Total top 4 operators	173.8	25.6%	165.7	25.8%	163.9	26.5%
All other operators	505.6	74.4%	476.8	74.2%	454.1	73.5%
Total	679.4	100.0%	642.5	100.0%	621.6	100.0%

APM Terminals ranked third globally among port and terminal operating companies in terms of equity-weighted container throughput market share, handling 5.5% of the global container market in 2014, as calculated by Drewry Shipping Consultants; (APM Terminals' internal data uses a 38.3 million TEU by equity share figure).

The four leading port and terminal operating companies, which include The Port of Singapore Authority (PSA), Hutchison Port Holdings (HPH), of Hong Kong, and Dubai Ports World (DPW), combined handled just over one quarter (25.6%) of the global market, falling slightly over the past two years as new global competitors, notably China Merchants, have become more active. *(Source: Drewry, August 2015)*

Appendix 5

Quick Sort algorithm code example

Pseudo Code for recursive QuickSort function :

```
/* low  --> Starting index,  high  --> Ending index */
quickSort(arr[], low, high)
{
    if (low < high)
    {
        /* pi is partitioning index, arr[pi] is now
           at right place */
        pi = partition(arr, low, high);

        quickSort(arr, low, pi - 1);  // Before pi
        quickSort(arr, pi + 1, high); // After pi
    }
}
```

Partition Algorithm

```
/* low  --> Starting index,  high  --> Ending index */
quickSort(arr[], low, high)
{
    if (low < high)
    {
        /* pi is partitioning index, arr[p] is now
           at right place */
        pi = partition(arr, low, high);

        quickSort(arr, low, pi - 1);  // Before pi
        quickSort(arr, pi + 1, high); // After pi
    }
}
```

Appendix 6

Below is the Service Payload that is being retrieved from the GCSS data enrichment call, this contains the booking details as marked below:

<?xml version="1.0"?>

-<soapenv:Envelope xmlns:soapenv="http://schemas.xmlsoap.org/soap/envelope/">

-<soapenv:Header>

-<v1:CommonIdentifierResponse xmlns:v1="http://services.apmoller.net/ManagementFramework/CommonIdentifier/v2">

-<v1:ApplicationResponder>

<v1:TransactionID>RIDJYKIO47IBY18A</v1:TransactionID>

<v1:StatusCode>1</v1:StatusCode>

</v1:ApplicationResponder>

</v1:CommonIdentifierResponse>

</soapenv:Header>

-<soapenv:Body>

-<p:GetShipmentBookingDataServiceResponse xmlns:v2="http://services.apmoller.net/ManagementFramework/CommonIdentifier/v2" xmlns:p="http://services.apmoller.net/AMM/ GetShipmentBookingDataServiceResponse

-<p:ShipmentDnDresponse>

<p:ShipmentPriceCalculationDate>2016-08-03</p:ShipmentPriceCalculationDate>

-<p:TransportDocument>

<p:TransportDocumentNumber>500008621</p:TransportDocumentNumber>

</p:TransportDocument>

<p:ShipmentNumber>500008621</p:ShipmentNumber>

<p:BookingOffice>London</p:BookingOffice>

+<p:ShipmentPartyRoles>

<p:IsNAP>false</p:IsNAP>

</p:Vessel>

-<p:ReceiptShipment>

-<p:ReceiptContainert>

<p:ReceiptDeliveryCode>CY</p:ReceiptDeliveryCode>

</p:ReceiptShipment>

-<p:DeliveryShipment>

<p:ReceiptDeliveryCode>CY</p:ReceiptDeliveryCode>

</p:DeliveryShipment>

-<p:Operator>

-<p:AlternativeCode>

<p:AlternativeCodeVal>1</p:AlternativeCodeVal>

</p:AlternativeCode>

<p:OperatorName>MAEU</p:OperatorName>

</p:Operator>

<p:ETD>2016-08-03T02:00:00</p:ETD> **(Retrieved from GSIS)**

<p:ETA>2016-08-15T13:00:00</p:ETA> **(Retrieved from GSIS)**

<p:FMCRegulationFlag>true</p:FMCRegulationFlag>

-<p:ShipmentRoute>

-<p:RouteCode>

<p:JourneyGroupCd>T2</p:JourneyGroupCd>

</p:RouteCode>

-<p:CardinalDirection>

<p:CardinalDirectionCd>W</p:CardinalDirectionCd>

</p:CardinalDirection>

<p:Origin>DEBRV</p:Origin>

<p:Destination>USNWK</p:Destination>

<p:OriginCY>DEBRV06</p:OriginCY>

<p:DestinationCY>USNWKTM</p:DestinationCY>

-<p:PortOfLoadDetails>

-<p:Port>

<p:DefinedAreaName>MSC Gate Bremerhaven Gmbh & Co. KG</p:DefinedAreaName>

<p:DefinedAreaCd>DEBRV06</p:DefinedAreaCd>

</p:Port>

-<p:VesselDetails>

<p:VesselTypeCd>MVS</p:VesselTypeCd>

<p:VesselName>MAERSK OHIO</p:VesselName>

<p:VesselCode>027</p:VesselCode>

</p:VesselDetails>

</p:PortOfLoadDetails>

-<p:PortOfDischargeDetails>

-<p:Port>

<p:DefinedAreaName>Port Newark Container Terminal F577</p:DefinedAreaName>

<p:DefinedAreaCd>USNWKTM</p:DefinedAreaCd>

</p:Port>

-<p:Container>

<p:ISOSerialNum>AWSD9875670</p:ISOSerialNum> **(EPCglobal ISO number).**

-<p:ContainerPartyRoles>

-<p:Payers>

<p:PayerType>Import Detention Payer</p:PayerType>

<p:PayerCode>100115657</p:PayerCode>

<p:PayerTpDoc>500008621</p:PayerTpDoc>

</p:Payers>

-<p:Payers>

<p:PayerType>Import Demurrage Payer</p:PayerType>

<p:PayerCode>100115657</p:PayerCode>

<p:PayerTpDoc>500008621</p:PayerTpDoc>

</p:Payers>

</p:ContainerPartyRoles>

<p:NonOperating>false</p:NonOperating>

<p:Empty>false</p:Empty>

<p:IsShipperOwned>true</p:IsShipperOwned>

-<p:ContainerSizeType>

<p:ContainerSizeTypeCd>20DRY</p:ContainerSizeTypeCd>

</p:ContainerSizeType>

-<p:Commodity>

<p:CommodityClassificationCd>000101</p:CommodityClassificationCd>

</p:Commodity>

</p:Container>

-<p:ShipmentTransportPlan>

-<p:ServiceMode>

<p:ServiceModeCd>CY/CY</p:ServiceModeCd>

</p:ServiceMode>

-<p:TransportPlan>

<p:TransportType>Prd</p:TransportType>

-<p:Legs>

<p:StartLocation>DEBRV06</p:StartLocation>

<p:StartLocationCountry>DE</p:StartLocationCountry>

<p:StartLocationState>HB</p:StartLocationState>

<p:StartLocationTerminalName>MSC Gate Bremerhaven Gmbh & Co. KG</p:StartLocationTerminalName>

<p:EndLocation>USNWKTM</p:EndLocation>

<p:EndLocationCountry>US</p:EndLocationCountry>

<p:EndLocationState>NJ</p:EndLocationState>

<p:EndLocationTerminalName>Port Newark Container Terminal F577</p:EndLocationTerminalName>

<p:LegSequenceInRoute>1</p:LegSequenceInRoute>

<p:GCSSExpectedDepartureDateTime>2016-08-03T03:00:00</p:GCSSExpectedDepartureDateTime>

<p:GCSSExpectedArrivalDateTime>2016-08-15T08:00:00</p:GCSSExpectedArrivalDateTime>

<p:GCSSExpectedDepartureDateTimeUTC>2016-08-
03T02:00:00</p:GCSSExpectedDepartureDateTimeUTC>

<p:GCSSExpectedArrivalDateTimeUTC>2016-08-15T13:00:00</p:GCSSExpectedArrivalDateTimeUTC>

<p:GCSSLastFreeDays>2016-08-15T13:00:00</p:GCSSExpectedArrivalDateTimeUTC>

<p:GCSSExpectedCustomerPickUp>2016-08-15T13:00:00</p:GCSSExpectedArrivalDateTimeUTC>

-<p:TransportMode>

<p:TransportModeCd>MVS</p:TransportModeCd>

</p:TransportMode>

</p:Legs>

</p:TransportPlan>

-<p:TransportPlan>

<p:TransportType>Oper</p:TransportType>

-<p:Legs>

<p:StartLocation>DEBRV06</p:StartLocation>

<p:StartLocationCountry>DE</p:StartLocationCountry>

<p:StartLocationState>HB</p:StartLocationState>

<p:StartLocationTerminalName>MSC Gate Bremerhaven Gmbh & Co. KG</p:StartLocationTerminalName>

<p:EndLocation>USNWKTM</p:EndLocation>

<p:EndLocationCountry>US</p:EndLocationCountry>

<p:EndLocationState>NJ</p:EndLocationState>

<p:EndLocationTerminalName>Port Newark Container Terminal F577</p:EndLocationTerminalName>

<p:LegSequenceInRoute>1</p:LegSequenceInRoute>

<p:GCSSExpectedDepartureDateTime>2016-08-03T03:00:00</p:GCSSExpectedDepartureDateTime>

<p:GCSSExpectedArrivalDateTime>2016-08-15T08:00:00</p:GCSSExpectedArrivalDateTime>

<p:GCSSExpectedDepartureDateTimeUTC>2016-08-03T02:00:00</p:GCSSExpectedDepartureDateTimeUTC>

<p:GCSSExpectedArrivalDateTimeUTC>2016-08-15T13:00:00</p:GCSSExpectedArrivalDateTimeUTC>

-<p:TransportMode>

<p:TransportModeCd>MVS</p:TransportModeCd>

</p:TransportMode>

</p:Legs>

</p:TransportPlan>

-<p:MerchantHaulageMode>

<p:EquipmentAssignmentId>2CBJLLULLYUJB</p:EquipmentAssignmentId>

-<p:EquipmentNumber>

<p:AlternativeCodeVal>ABCD1234567</p:AlternativeCodeVal>

</p:EquipmentNumber>

<p:ExportReturnLocation>DEBRV06</p:ExportReturnLocation>

</p:MerchantHaulageMode>

</p:ShipmentTransportPlan>

</p:ShipmentDnDresponse>

</p:GetShipmentDnDDetailsResponse>

</soapenv:Body>

</soapenv:Envelope>

Appendix 7

The XML data for GSIS are the same as GCSS seen in Appendix 6. The only difference is in the Data Items that are being called. The specific data items for GSIS XML payload call can be seen below:

Data Item
Service Response (GetVesselScheduleByVoyage)
Actual Arrival Date
Actual Departure Date
Vessel ID
Vessel Name
TerminalLocation
Terminal Name
Terminal Code
ArrVoyage
DepVoyage
GSIS Key