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TAMPERE UNIVERSITY OF TECHNOLOGY

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DEVELOPING A PRODUCT-SERVICE SYSTEM FOR AUTOMATION RETROFIT OFFERING

Master of Science Thesis

Examiner: Professor Jose Martinez Lastra
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ABSTRACT

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It has been a growing trend for decades to replace human labour with automation. The goal is to increase productivity and worker safety while decreasing costs and human errors. However, investing on new, high technology automated machines is expensive. Retrofitting computing systems with state-of-the art equipment provides important benefits at a low cost. The goal of this thesis is to clarify the retrofit process and resources needed to execute it.

This thesis is a study on how to create a product-service system for one automation retrofit solution. A product-service system is defined as a concept, which combines products and services into one offering that creates new and additional value to customer as well as strengthens organisation's market position. The goal of this research is to examine product-service system models and select a suitable one to carry out in the target company.

The research is divided into two sections. The literature and industrial practises review studies the current state of retrofits, the division of duties between humans and automation and product-service systems. The review is used to create a theoretical framework for automation retrofits, which is validated in the empirical part of the thesis. The research methods used in the empirical part are interviews and benchmarking. The interviews aim to collect data about the current state of retrofitting and challenges inside the target company. The benchmarking is carried out in two companies, who have done retrofitting in their own business areas, to investigate targets for development. Analysing the data gathered from both interviews and benchmarking validates the created framework.

The thesis offers a methodology for adopting a retrofit product-service system in container handling field. The emphasis is put on clarifying the process flow to customers as well as identifying the key areas, which should be improved. As a result, a series of documents explaining the retrofit process to customers is created and suggestions are given to the target company how to improve the current process flow. Challenges are found especially in both internal and external communication as well as resource allocation and the onsite implementation time.

This thesis provides an overview of the current automation retrofit practices. The theoretical contribution fills the existing gap of limited number of automation retrofit applications. The framework created and the challenges found will give premises for future development of target company's retrofits.

TIIVISTELMÄ

ELISA KARI: Automaation jälkiasennuksen tuotteistaminen
Tampereen teknillinen yliopisto
Diplomityö, 74 sivua, 4 liitesivua
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Avainsanat: retrofit, tuotteistaminen, jälkiasennus

Automaation käyttö manuaalisen työn korvaajana on yleistynyt viime vuosikymmeninä. Tavoitteena on parantaa niin tuottavuutta kuin työntekijöiden turvallisuutta samalla vähentäen kuluja ja inhimillisiä virheitä. Investointi uusiin, korkean teknologian automaattisiin laitteistoihin on kuitenkin kallista. Uusien komponenttien jälkiasentaminen vanhaan, mutta toimivaan työkoneeseen mahdollistaa automaation tuomat edut vain murto-osalla uuden koneen hinnasta. Tämän tutkimuksen tarkoituksena on selventää jälkiasennusprosessia sekä resursseja, joita tarvitaan sen toteuttamiseen.

Tämän diplomityön tarkoituksena on tutkia automaation jälkiasennuksen tuotteistamista. Tuotteistaminen on määritelty käsitteenä, joka yhdistää palvelun ja tuotteen yhdeksi tarjoamaksi, joka luo asiakkaalle lisäarvoa sekä vahvistaa oman organisaation markkina-asemaa. Työn tarkoituksena on tutkia erilaisia tuotteistusmalleja ja valita niistä sopiva toteutettavaksi kohdeyrityksessä.

Diplomityö on jaettu kahteen osaan. Kirjallisuuskatsaus käsittelee jälkiasennusten, tuotteistuksen sekä ihmisen ja koneen välisen työnjaon nykytiloja. Katsauksen pohjalta luodaan teoreettinen viitekehys automaation jälkiasennukselle, joka validoidaan työn empiirisessä osassa. Empiirisen osan tutkimusmetodeina käytetään haastatteluja sekä vertailuanalyysia. Haastatteluiden tarkoituksena on kerätä dataa kohdeyrityksen sisältä jälkiasennuksen nykytilasta sekä haasteista. Vertailuanalyysi toteutetaan kahdessa yrityksessä, jotka ovat omilla toimialoillaan tehneet jälkiasennuksia. Näiden tarkoituksena on tutkia mahdollisia kehityskohteita. Kerätyn datan analysointi vahvistaa luotua viitekehystä.

Diplomityö esittelee metodologian jälkiasennuksen tuotteistamiseen konttienkäsittelyalalla. Painopiste on asetettu prosessin kulun selventämiseen asiakkaalle sekä parannettavien avainasioiden tunnistamiseen. Työn lopputuloksena luodaan sarja dokumentteja, joiden avulla jälkiasennusprosessi voidaan havainnollistaa asiakkaille sekä annetaan kohdeyrityksellä suosituksia parannuskohteista. Haasteiksi nostetaan erityisesti sekä sisäinen että ulkoinen kommunikaatio, resurssienjako sekä asennukseen tarvittava aika asiakkaan työmaalla.

Tämä diplomityö tarjoaa yleiskatsauksen tämänhetkisistä jälkiasennusten toimintatavoista. Työn teoreettinen osuus täyttää löydetyn aukon, sillä automaation jälkiasennuksen sovelluksia oli esillä vain rajattu määrä. Luotu viitekehys ja havaitut haasteet mahdollistavat pohjan tulevalle jälkiasennusten kehitykselle kohdeyrityksessä.

PREFACE

These past three years of my master's studies have been quite a rollercoaster. During this time, I have been sure a lot of times that I will never make it that far that I'm writing my thesis. Let alone that the thesis would actually ever see the light of day. More than once I was looking for the button that allows me to quit the university altogether. It's been quite a journey, but it's clear that I would not have done this alone.

I would like to thank Miikka Haapa-aho from Kalmar for offering me this topic, supervising my work and always having time to answer my questions. Thank you for the advice and encouragements during the thesis process. Also thanks to everyone at Kalmar, Sandvik and Valmet, who took the time to come to my interviews and answer all my questions, whether they were stupid or not. This would not have been possible without your input. I would like to thank professor Jose L. Martinez Lastra from Tampere University of Technology for supervising this thesis.

It took me seven years to get here from the start of my studies. It would have been impossible to go through this process without the support of my parents. Thank you for being there and for not saying that it's a crazy idea to apply to TUT after graduating from TAMK. Your support made it possible for me to live one or two of my biggest dreams during these years.

My deepest gratitude goes to Johanna and my dad for the help and ideas during the writing process and for proofreading the thesis. Finally, thank you Anu. Those endless coffee sessions really made a difference. Thank you for reminding me what my topic actually was every time I forgot where I was supposed to go.

"It's a dangerous business, Frodo, going out your door. You step onto the road, and if you don't keep your feet, there's no knowing where you might be swept off to."
– J.R.R. Tolkien

Tampere, 22.5.2018

Elisa Kari

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LIST OF SYMBOLS AND ABBREVIATIONS

AutoRTG	Automated Rubber-Tyred Gantry Crane
POS	Product-Oriented System
PSS	Product-Service System
ROS	Result-Oriented System
RTG	Rubber-Tyred Gantry Crane
TLS	Terminal Logistics System
TOS	Terminal Operating System
UOS	Use-Oriented System

1. INTRODUCTION

The use of automation over manual operations has been a growing trend for decades. Human labour is increasingly being replaced by robotics and automated machinery (Lennard, 2013). Automation brings a lot of benefits compared to manual labour, for example removing the risk of human errors, improving efficiency and consistency and reducing waiting times in operations (Salim, 2017). One of the biggest advantages is the improvement of worker safety, as possibly dangerous duties can be given to an automated device. The use of automation can also reduce the risk of minor injuries that might occur in manual labour. In addition, workers can be motivated by placing them to more intellectually challenging duties while automated machines and robots are taking care of the simpler, repetitive tasks. (Nichols, 2017.)

It doesn't come as a surprise that heavy machinery are substantial investments, which have the life expectancy of at least 10 years, possibly much longer. The problem with these machines is that their technology gets old and therefore they are not as efficient as they should be. Nevertheless, they are still functional. At this point, investing on a new expensive machine might not be the best choice, but something should be done to the ageing machines to maintain operational efficiency as high as possible.

Retrofitting means adding equipment to an existing system to correct a defect or add capability (Park and Allaby, 2017). Retrofitting can increase efficiency, reduce costs as well as improve occupational safety and working conditions. It can also enable automated operations to previously manual machines. (Kalmar, 2017a.) In addition, it is a lot cheaper to install new equipment onto an old machine than invest on a totally new machine.

It has been noticed that retrofitting as a concept might invoke negative images in customers, thus making it harder for manufactures to sell the idea (Mandel, 2010). Convincing the customers that investing on a properly engineered system can actually bring significant savings has been a difficult task. What is more, the process of retrofitting has been seen challenging since after purchasing, additional savings are hard to come by. (Rouse, 2007.) The goal of this thesis is to clarify one retrofit process and demonstrate that retrofitting does not mean a once in a lifetime investment and that it can bring savings and increase operational safety after the first purchase too.

This thesis is a study on developing a product-service system (PSS) for automation retrofits in the field of container handling and was commissioned by Kalmar, a cargo handling company. The thesis focuses on developing a PSS for RTG (rubber-tyred gantry crane) retrofits. In Kalmar’s solution, a manual RTG can be retrofitted into an AutoRTG via four automation levels. Both customer needs and the structure of the original machine define the automation level chosen for the retrofit process.

This chapter presents the premises to the thesis. First the need for the research is presented. Next, the research problem and thesis objectives are covered. The research questions are also listed. The scope of the thesis is explained in the third section and finally the structure of this thesis is presented in the fourth section.

1.1 Motivation and justification

The need for developing a PSS for the RTG retrofit became necessary when it was noticed, that for customers, it might be difficult to understand the benefits of automated machines over manually driven ones. Retrofitting an old RTG is currently an investment, the advantages of which might not be evident. It was also difficult to try to sell the idea of retrofitting to customers without a documentation that clearly indicates what is needed to make the retrofit happen, what limitations the machines set and how the customer benefits when buying the retrofit. The goal for the PSS process is to create a series of documents which can show the customer, what retrofitting actually means in Kalmar and how it is done. With this, the hope is to get customers more excited about the opportunities that the retrofit solutions can offer.

The theoretical contribution of this thesis is to fill the existing gap of automation retrofit applications. Currently a substantial number of studies made of retrofit applications can be found for example in building services engineering, but the amount of studies made in the field of automation is much more limited. This thesis aims to create a framework suitable for automation technology and present some process models to fill this gap.

1.2 Research problem and objectives

The purpose of this thesis is to analyse what is needed to retrofit an RTG to a certain automation level and use the gathered info to create materials that will make the concept of retrofitting easier for potential customers to understand. The first objective of this thesis is to gather information about RTGs and the retrofitting process from different departments in Kalmar and find the parts that could be or already are standardized. The second objective is to benchmark other companies’ use of retrofitting and find methods that could be utilized in Kalmar. The third objective is to use this information collected both inside and outside Kalmar to develop a service product, called the RTG retrofit. To achieve these goals the retrofitting process and RTG automation levels must be properly explored and the right target group for the interviews must be found.

The research questions, which are formulated based on the objectives, are the following:

1) How to successfully develop a product-service system for automation retrofits based on literature?
2) How the retrofits can be made to look more tangible and how to make it easier for the customers to see the benefits that retrofitting offers?
3) How to create a framework for developing a product-service system for retrofits in general, so that it can be used in the future when launching retrofits for other products?

1.3 Scope of the thesis

This thesis focuses on developing a product-service system for Kalmar RTG retrofits, with some limitations. The PSS process consists of defining the product, researching the field, designing, piloting and launching and finally evaluating and improving the created service product (Tuulaniemi, 2011). Also prizing, marketing, sales and follow-up can be seen as parts of a PSS process (Parantainen, 2007). In this thesis, the focus is put on researching the field and designing the product. Other parts are left out either because the target company has already defined them or because of the limitations of time given to produce the thesis. As the retrofit process in Kalmar usually takes up to 12 months from customer lead to project delivery, it is not possible to do follow-up or further develop the created product in this thesis. These parts are left for future research.

Currently the retrofits are done in Kalmar only to RTG machines. During the interviews it was pointed out that Kalmar has plans to extend retrofits to cover all the machines in their product portfolio (Interviewee 3, 2017). Thus this thesis only covers the retrofits done to RTG machines, leaving the rest of the product portfolio out.

1.4 Structure of the thesis

This thesis is divided into three parts: the theoretical part, empirical part and finally analysis of the results and suggestions for future studies. Chapter 2 covers the literature and industrial practises review. The selected topics to be discussed are automation retrofits, the division of duties between humans and automation and the concept of product-service system. Chapter 3 introduces the research methods used in this thesis. It also presents additional material needed to carry out the empirical part. The chapter ends with a section, which presents the proposal to solve the research problem.

Chapter 4 discusses the implementation of the previously presented proposal. First, the results from the interviews are analysed followed by the analysis made from the benchmarking. The chapter ends with a description about the PSS process implemented, which based on the data gathered from the literature review, interviews and benchmarking. Chapter 5 consists of the conclusions and evaluation of the results and thesis process itself. The research questions are presented once more and answers to them are provided. The thesis ends with a discussion about topics for further research.

2. LITERATURE AND INDUSTRIAL PRACTICES REVIEW

This chapter reviews the literature related to automation retrofits and product-service systems and is divided into two sections. The first part covers the basis of automation retrofits and discusses the reasons why humans are being replaced by automation, presenting the basis and justification to the need for this research. The section also discusses insights into why humans are still needed to monitor and possibly control the automation and cannot be totally removed from the operation.

The second part discusses product-service system development. First the term product-service system is introduced. The section continues with discussion about different types of product-service systems and the barriers and drivers for its adoption. The section ends with discussion about why a product should be standardized.

2.1 Automation retrofit

The demand for automated machines and greater efficiency has increased in industrial sectors over the years. Using automation as a way to simplify precision control requirements in manufacturing processes can lead to significant cost savings, higher productivity and better utilization of humans and machines in the work process. (Kiran Kumar and Nagendra Prasad, 2014.) Automation can be seen as a way to lower production costs, as standardized low variety and high volume production can be performed efficiently (Sjøbakk et al., 2014).

According to Oxford Dictionaries (2017), retrofitting means adding a component to something that did not have it when manufactured. These components are presented in bill of materials (BOM), which is used to depict a product's component structure. Traditionally a BOM is created for each product separately, but customer-oriented products have made this impossible. (Hernández Matías et al., 2008.) A generic BOM is used in these cases to describe the product with attributes, which can be chosen depending on customer's wishes (Olsen et al., 1997).

Retrofitting can be seen as adding equipment to an operating plant. The purpose of retrofitting is to gain some advantage, for example updating the plant without massive investments. It can be used to add value and improve quality to processes by using inexpensive technological inputs. (Larkin, 1984.) With retrofitting, the life expectancy of an old machine can be increased and many of the benefits of a new machine can be achieved with a fraction of the cost of a new machine (Kiran Kumar and Nagendra Prasad, 2014).

There are three reasons for doing retrofitting: decreasing maintenance, increasing productivity and inspecting quality issues. First, ageing machines are prone to more breakdowns, which causes production stops and high maintenance costs. Updating the old components, cabling or electronics will lead to less maintenance and breakdowns. (Tryling, 2004.) Another benefit of retrofitting is the time that is needed to get the machine up and running. In most cases, it is faster to retrofit the old machine with new parts than build a completely new machine. (Kiran Kumar and Nagendra Prasad, 2014.)

Heavy machinery can stay in operation for decades. During that time a lot of technological advances are made, and the machines require upgrading to keep up with the new technologies. As safety awareness increases, the old machines might not meet the safety regulations issued a decade after the purchase of the machine. Another growing trend is environmental awareness leading to new emission regulations, which the old machine might not reach on its own. Retrofitting the old machine with new parts can offer solutions to these issues. (Larkin, 1984.)

As machines get older they start presenting problems that increase for example maintenance costs and down time of the machines. Other problems that can emerge are reduced productivity as well as increased amount of support systems and repairs. Retrofitting the old machines can help overcome these problems. (Kiran Kumar and Nagendra Prasad, 2014.)

The demands for production lines increase constantly, as production costs need to be reduced while productivity and product quality must be improved. Old, manually operated machines might not be able to perform such tasks, which could cause the productivity not reaching its target. Automated machines could offer a solution to this problem but making an expensive investment while the old machines still have years left of their life expectancy, might seem like a waste of money. Retrofitting manually working machines with automation kits can increase productivity and maintain the flexibility of the manual use. Retrofitting the existing machines into automated ones is an inexpensive investment compared to investing into brand new automated machines. (Forsman, 2010.)

2.1.1 The advantages and disadvantages of automation

Industrial automation is used to control machinery and processes to optimize productivity and delivery of services. Automation also reduces the need for human labour, which increases occupational safety as humans can be taken out from hazardous working environments. The use of automation also increases the quality of the manufacturing process as well as consistency of the output. (Kiran Kumar and Nagendra Prasad, 2014.) It is also possible to lower production costs when using automated operations instead of manual operations via reduced labour costs, decreased production cycle times and increased quality. The use of automation is an effective tool to gain these benefits especially when concentrating on high-volume, low-variety production. (Sjøbakk et al., 2014.)

It is argued that automation can take over from humans the tasks that are not creative and personal, which usually means tasks that are predictable and repetitive. Humans are not that keen on doing those tasks, so taking them away can offer opportunities that raise motivation. (Mortensen, 2017.) Automation can also improve efficiency and create new kinds of jobs. This will lead to the growth of economy. (Rotman, 2017.).

Although automation offers significant benefits over manual labour, there are still cases, where humans perform work tasks better than machines. For example, customized products and low volumes are usually such tasks (Sjøbakk et al., 2014). It is also argued that automation does not perform well in tasks that require critical thinking, creativity or leadership skills (Mortensen, 2017).

One of the most common negative images about automation is that it is used to replace humans, even though it is only intended to change the nature of the division of duties (Haight and Kecojevic, 2005). It is in fact pointed out that a robot should be controlled minimum by two humans to secure safe operation. A higher automation levels mean more supervision by humans. (Chen and Barnes, 2014.)

It is mentioned that even though automation is meant to be smarter than human, it is still created by humans. This means that the same restrictions exist in both. A human cannot plan and design an automated reaction to every possible action that happen in operation. Thus, the system should be designed to have as many reactions as possible and allow the human supervisor take control when the unexpected happens. (Haight and Kecojevic, 2005.) Also, the human-automation interaction should be paid close attention to, as communication errors lead to the automation misunderstanding the commands received. (Chen and Barnes, 2014.)

Another disadvantage of automation is that it lacks the flexibility of humans. It can only perform the tasks that are pre-set for it. (Chen and Barnes, 2014.) At the same time, humans bring attributes such as judgement, logic and experience. Humans can interact with unexpected events and adapt to changes. It is also pointed out that a manual user of a machine or system has intangible experience of the machine and its attributes, which the operator cannot acquire at the same extent. (Haight and Kecojevic, 2005.)

Table 1 presents the strengths and weaknesses for both humans and automated machines. As it can be seen from the table, humans are able to adapt to changes and can interact with the machine, whereas the machine cannot be ready to all possible events that might occur during operation. On the other hand, machines are more efficient and uniform, whereas humans are more prone to errors and are sometimes unreliable.

Table 1. *The strengths and weaknesses of humans and machines (Chen and Barnes, 2014)*

Human		Machine	
Strengths	Weaknesses	Strengths	Weaknesses
Can apply judgment	Inconsistent	Consistent	No judgment
Adaptable	Subject to errors	Predictable	Cannot be programmed for all eventualities
Can apply sentient knowledge	Unpredictable and possibly unreliable	Efficient	No sentient knowledge
Interactive	Subject to emotion and motivations	Uniform and reliable	Constrained by human limitations in design, installation, and use

Even though the benefits of automation are quite clear and easy to argument, its adoption is slow. Some reasons for this are lack of tools and methodologies that support companies in decision making and high risk of unsuccessful investments. Too much capacity and excess functionality are also common problems in production equipment investments. (Sjøbakk et al., 2014.) The adoption of automation can also be rather expensive, as the investment, implementation and extra human resources create additional costs (Karhu et al., 2009).

2.1.2 Human centered automation

Although automation can be used in most systems, it has its limitations. For example in a complex system, automation is not able to do everything that is needed to complete the tasks and the help of humans is needed. In most cases the problem is that automation is not able to detect when it is itself failing and how to correct the failures. Humans are needed to monitor the automation and to take the lead when failures happen. The process where automation does most of the work while humans monitor it and take actions if needed is called human centered automation. (Sheridan, 1995.)

Human centered automation has several definitions. The basic principle is that it describes the operational environment where both machines and humans work in co-operation (Inagaki, 2006). This means that humans are given the tasks most suitable to them and automation is given the tasks which are most suitable for it. On the other hand, it can mean keeping the human operator in the control loop or as the authority over automation. Another definition is using automation as a way to reduce human error. (Sheridan, 1995.) Automation is in fact used to assist active operators. Also, one definition is that automation compensates the weaknesses that humans have while backing up the capabilities and strengths. (Mitchell, 2003.) Most importantly, the concept relies on the fact that humans are responsible for safety (Furukawa and Parasuraman, 2003). Table 2 elaborates the basic principles on human-centered automation.

Table 2. *The principles of human-centered automation (adapted from Inagaki, 2006)*

The human bears the ultimate responsibility for safety
Therefore:
• The human must be in command
• To command effectively, the human must be involved
• To be involved, the human must be informed
• Functions must be automated only if there is a good reason for doing so
• The human must be able to monitor the automated system
• Automated systems must, therefore, be predictable
• Automated systems must be able to monitor the human operator
• Each element of the system must have knowledge of the others' intent
• Automation must be designed to be simple to learn and operate

The downside of human centered automation is that when humans are put to monitor and supervise the automation and only act in case of a failure, they might get bored and do not perform their duties well (Sheridan, 1995). As automation is usually fast and handles substantial amounts of information, the operator can be overwhelmed (Furukawa and Parasuraman, 2003). It is also mentioned that it is not possible for a human to monitor the automation effectively if there are only a little operations happening and not much needed to be done. As humans are prone to errors, they might ask the automation to do wrong things or put it to wrong mode during operation. (Bainbridge, 1982.)

It is also possible that the humans loose the situational awareness, meaning that they might not know what the automation is doing (Inagaki, 2006). This leads to the fact that when humans need to take action, they might not be aware of the whole problem and are not able to predict what should be done next (Sheridan, 1995). It is also emphasised that if the way which automation operates is not familiar to humans, problems can occur (Oishi et al., 2016). Also if humans are taken out of the daily operations, their skills get rusty and they might be inexperienced to perform manual operations when needed (Bainbridge, 1982).

When choosing to adopt human centered automation, the right candidate process is not that easy to find. Simple tasks are usually easier and faster for humans to carry out themselves rather than start programming and teaching the machines what to do. On the other hand, tasks that require lots of thinking are also bad candidates as it might turn out too difficult to program the machines to understand the whole problem. (Sheridan, 1995.) In fact human operators are needed more and more when the automated control system is too advanced (Bainbridge, 1982). The best case to use human centered automation is tasks that are not too hard to program and which's implementation would be time consuming (Sheridan, 1995).

Even though there are significant advances in automation, it does not always create just benefits (Flemisch et al., 2012). If the simple tasks are taken away from humans, it could create more difficult tasks for automation. It can also be seen as a problem that automation is used to do the job better than humans, but in order to do so, the automation needs humans to supervise it and operate if needed. (Bainbridge, 1982.) Machines that have more and more automated assistance create problems such as how to communicate with humans and who is responsible for what tasks (Flemisch et al., 2012).

Figure 1 presents one definition for the automation levels. In this definition, automation means full or partial replacement of human labour. It can be seen that the use of automation has a lot of variance depending on where it is used and it is not only a choice between no automation and full automation. The figure shows how different human centered automation can be depending on the process it is used in. For example in level 2, which is a low automation level, the computer only offers solutions and human makes all the decisions. Then again in level 9, which is high automation level, the computer makes almost all the decisions independently, only informing the human if something unexpected happens. (Parasuraman et al., 2000.)

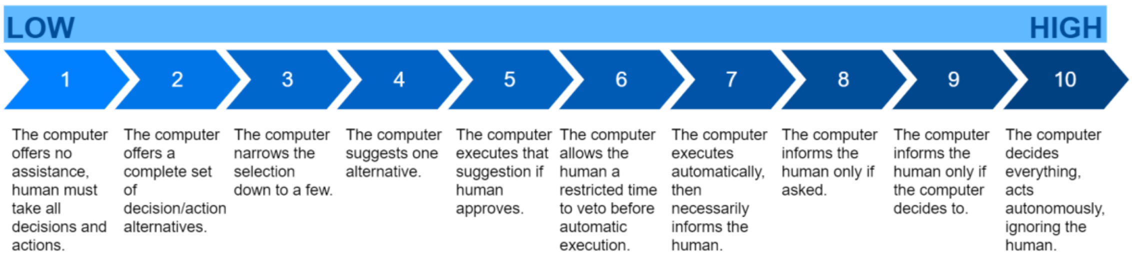

Figure 1. *The levels of automation (adapted from Parasuraman et al., 2000)*

Figure 2 elaborates sharing control between human and machine. First, there can be seen the simplest way to share control, which is no sharing. Either the human or the machine does everything. As discussed earlier in this chapter, this is not the best way to use machines and humans, since machines needs humans to monitor the work and humans are not efficient enough to perform every task. This will lead again to human centered automation, where control is shared between human and automation. (Flemisch et al., 2012.)

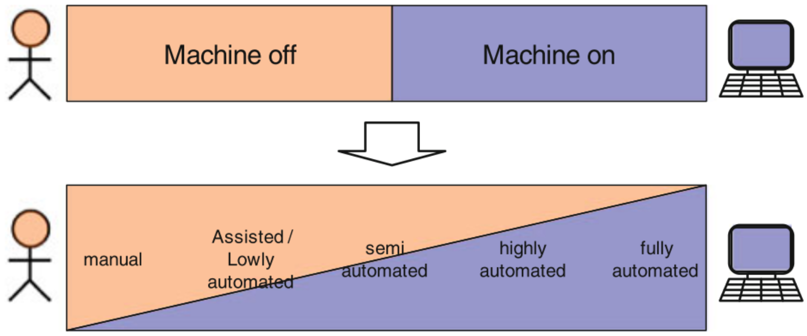

Figure 2. *The continuous assistance and automation scale (Flemisch et al., 2012)*

As seen in the second part of Figure 2, there are several ways to share control between the machine and human. This model has five levels and it is much simpler than the one presented in Figure 1. This is called the continuous assistance and automation scale. Between the manual and fully automated operations there are three levels, where control is shared between these two operations. The first one is assisted/lowly automated, where human does most of the operations and automation only assists if needed. The second one is called semi-automated, where the human operator and the machine work together dividing the work duties. The third one is highly automated, where machine does most of the operations and human assists if needed. (Flemisch et al., 2012.) This level matches with the definition of human centered automation given earlier (Sheridan, 1995), but it can be seen that humans and machines can work together in many levels, not just one.

The Society of Automotive Engineers (SAE) has designed a J3016 recommendation, which classifies on-road motor vehicles into six levels based on the ratio between automation and manual driving. This model is presented in Table 3. Although it is only a recommendation, not a legislative regulation, it is widely used by car manufacturers to describe technological advances made. It is noted that most manufactured cars are level 0 or 1 and level 2 can be nearly reached at the moment. Going beyond level 2, the type approval restrictions are not yet fulfilled and thus at the moment there are no level 3 or higher car on roads. (Nieminen, 2018.)

Table 3. *Vehicle automation levels (Payne, 2017)*

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Although the SAE model has been created for on-road vehicles, the levels of automation can be applied in other fields too. Comparing this model to the two introduced previously in Figure 1 and Figure 2, the levels can be seen following the same pattern. The lowest level is manual operation and the highest full automation. There are four levels in between, increasing the level of automation and decreasing the amount of manual operations needed. This makes the model presented in Figure 1 the most detailed and the model in Figure 2 the most straightforward, placing the model in Table 3 in between.

As discussed, humans and machines can divide their workload in several ways and there is no defined theory of how many levels there are between fully automated and fully manual operations. Some ways to define the suitable level are suggested, first of which is thinking about the human-machine interaction and designing the automation so that it supports this. Second, it should be thought when the operation is too automated and humans are not in the decision making. Finally, it should be discussed if the automation level can be changed automatically or should human be the one who decides the current level that is used. (Oishi et al., 2016.)

2.1.3 The retrofit process

This section presents some models for the retrofit process. The biggest reason to choose retrofitting over investing into a new machine is that some parts of the old machine are acceptable as is and only need some updating. Usually these are the mechanical parts of the machine. (Tryling, 2004.) Also, investing on a retrofit is cheaper than purchasing a new machine and the payback time is usually shorter. This means that a retrofit is less dependent on long term reliability planning. (Hoffmann, 2007.) However, replacing the old parts with other parts that enable automation is not enough to make retrofit work. A machine retrofitting is a different process from building a new machine from scratch. It is crucial to know the history of the machine and the goals that are set for the automated controls in order to focus on the productivity and quality requirements that should be improved. (Tryling, 2004.) Figure 3 presents a flowchart of the decision making process when choosing between retrofitting and buying a new machine.

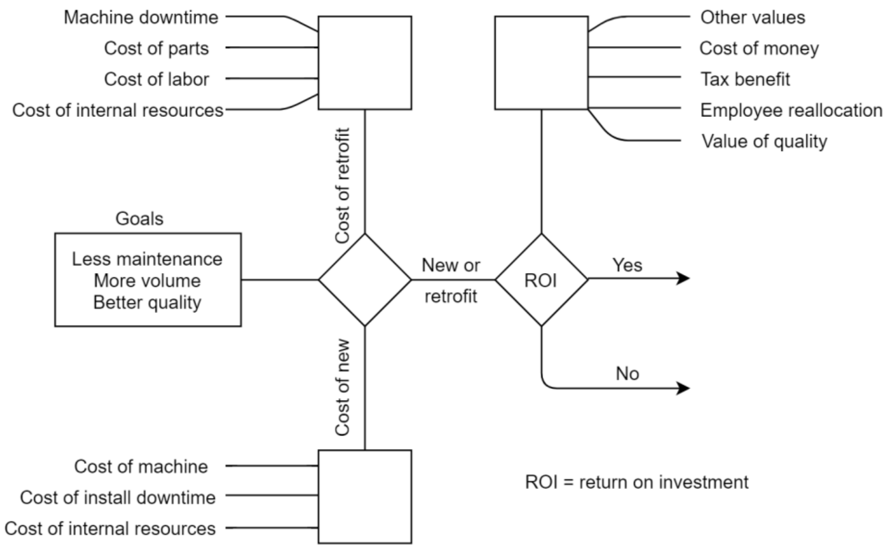

Figure 3*. Flowchart of decision making process for machine upgrade or replacement (Tryling, 2004)*

There are several different ways how retrofitting process can go through. One of them is presented in Figure 4. This process consists of four steps, first of them being defining why the retrofitting should be done, what benefits the old machine has and what problems should be fixed. After defining these, the next step consists of understanding the machine itself. Without the knowledge of how the machine should operate and what unique features the machine has, it is not possible to get the most out of retrofitting. Usually the people in charge of machine's maintenance are the best ones to consult to get the needed information. (Tryling, 2004.)

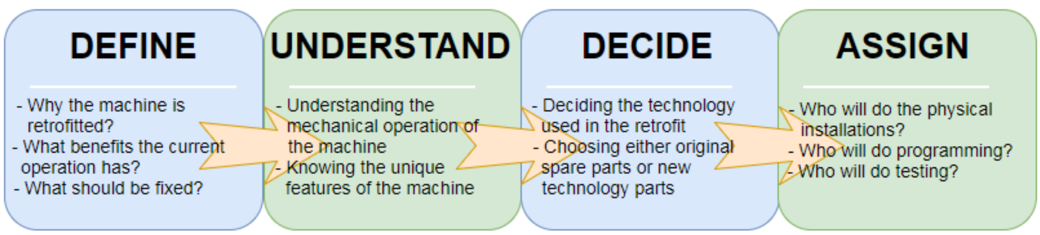

Figure 4. *Retrofit process (adapted from Tryling, 2004)*

The third step in this model is deciding the direction, where the retrofitting should take the machine. Usually this means deciding on what technology should be used. In some cases, the original spare parts meant for the machine might still be available, but new technology could offer an opportunity for a new technological direction for the machine. The final step in the retrofitting process is deciding, who will do the physical work, who will oversee programming of the needed devices and who will be in charge of testing the machine. It is essential to choose the right people to do these steps. Some plants might have the needed personnel themselves, but some might need help from a subcontractor. After all the installations and programming is done, it is important to test the new, retrofitted machine so that it works accordingly before taking it into production. (Tryling, 2004.)

Figure 5 present another model for the retrofit process. This model too has four steps, but they vary from the model presented earlier. The first step in this model is planning, which consists of setting goals, selecting team and benchmarking. Setting the goals require project planning so that the goals are in align with the process itself and the outputs that are desired. Selecting the right team is also crucial to get the hoped outcome. A successful retrofit project needs participation from people who have different skills and knowledge. Benchmarking against similar cases offers references on how the retrofitting could be done. (Sanders et al., 2012.)

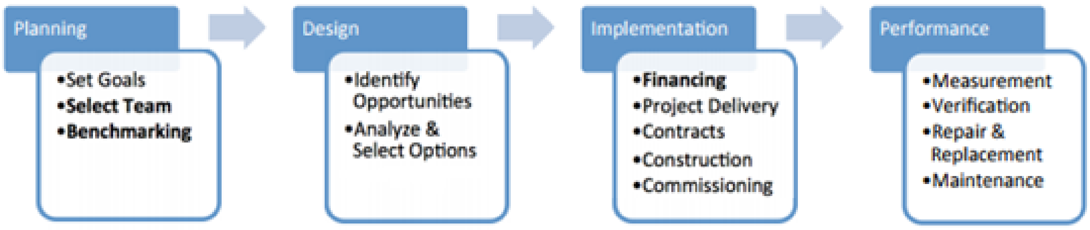

Figure 5. *Retrofit steps and activities (Sanders et al., 2012)*

The second step is designing, which consists of identifying opportunities and analysing and selecting options. Identifying opportunities can be done with preliminary audits. After that all possible options are analysed and selected factors that influence the process are balanced. The third step is implementation, which includes financing, project delivery, contracts, construction and commissioning. At this point it is important to discuss, how the project is financed and how much resources are available for implementation. The next phase is to decide what kind of project delivery is used. This depends highly on the available resources and the skills of the project team. Managing contracts should also be discussed at this point, as project delivery terms influence the contracts. Next the actual construction should be inspected. Retrofit processes are harder to implement as the working conditions on site cannot be totally evaluated beforehand. The step ends with commissioning, where the built retrofit solution's quality is checked and correct operation is ensured. (Sanders et al., 2012.)

The final step is performance, which includes measurement, verification, maintenance, repair and replacement. Measurement and verification is used to inspect that the intended savings are actually reached and that the solution compares with the benchmarking results. Repair and replacement thinks about the equipment which lifecycle will come to an end during the intended operation time. Finally maintenance is used to take care of the existing equipment. (Sanders et al., 2012.)

2.2 Product-service system

A product can be defined as a tangible object, which is manufactured in a purpose that it will be sold. A service is defined as an intangible object or activity, which is performed in order to gain value. (Goedkoop et al., 1999.) Combining these attributes create the concept of product-service system (PSS), which is elaborated in Figure 6. PSS is used to take the focus away from the traditional business model of selling and designing physical products and moves it to an orientation that investigates the benefits and functionalities of products and services (Bezerra Barquet et al., 2013). When manufacturing traditional products, the core of the business is the physical product. A service provider's core is providing aftermarket activities. With PSS, the focus is put on to the customer's actions with the product and the activities related to it. (Tan, 2010.) The relationship with the customer is emphasised, as combining skills, knowledge and resources increase the value received (Bezerra Barquet et al., 2013). With PSS, the customer does not necessarily purchase a product but an asset, which reduces the risks and costs related to owning a product (Baines et al., 2007).

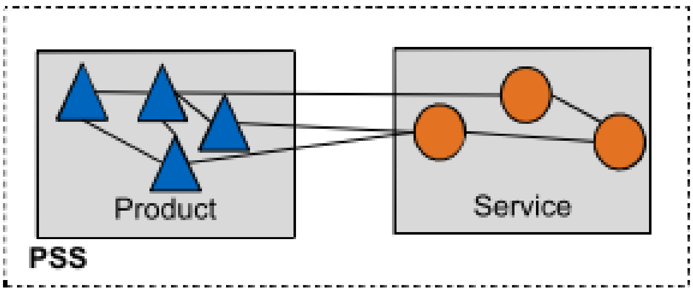

Figure 6. *PSS structure (Schenkl et al., 2013)*

Defining a service means clarifying what the service includes, what its purpose is and how it is implemented. Recognizing the tangible and intangible aspects is important, so that the service can be better suited for customer's needs. The service is usually divided into core service and support services. Core service defines the most relevant aspects of the service and answers to why the customer would want to buy the service. Support services create extra value to the core service and they can either be included in the service product or bought separately if needed. It is important to recognize the necessary support services so that they also can be taken into account when defining the resources that are needed to create a service product.(Jaakkola et al., 2007.)

Figure 7 depicts the evolution from products and services to a product-service system. The traditional bisection of an organisation's offering changes when products start to have service-like attributes and vice versa. Terms such as servitization and productization are seen as keywords related to PSS and used to describe the change towards it. PSS is seen as a way to maintain competitiveness especially in business areas where the low-cost labour countries are significant challengers. (Baines et al., 2007.)

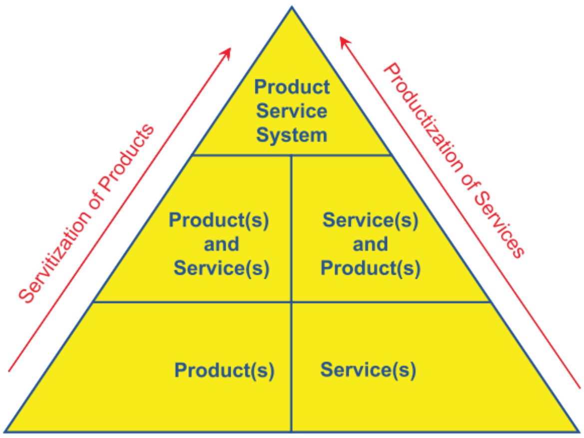

Figure 7. *Forming of the product-service system (Baines et al., 2007)*

The adoption of PSS requires changes being made in the organisation's business as the products are not manufactured the same way as before. It is vital to support the customers during the whole lifecycle of the service. Identifying these changes is seen as a major challenge for companies. A proposed solution to this is creating business models, which present operations and relationships that define the business. (Bezerra Barquet et al., 2013.) It is also noteworthy that a PSS does not need to be provided by a single company and it can be done in an alliance (Goedkoop et al., 1999).

PSS creates a combination of products and services to meet the changing needs of the customer. The focus is in providing services, which the products support. An important factor in delivering PSS is co-operation with providers, customers and partners. A traditional product is owned and maintained by the customer after purchasing, but in product-service systems, the customer might not own the product. (Bezerra Barquet et al., 2013.) When developing a product-service system, the customer's point of view should be included at the early stages to ensure that the designed offering meets the requirements of the customer (Baines et al., 2007). It is in fact an important notion that the customer is not really interested in a product or a service, rather the opportunities they offer. Customer seeks more satisfaction than just a physical item. (Manzini and Vezzoli, 2003.)

Table 4 elaborates the advantages of adopting PSS for both customers and companies. For the customer, the more customized offering creates value, as the combination of products and services meet the customer's needs better. For companies, PSS creates competitive advantage and new opportunities for markets. The co-operation between customer and supplier strengthens the relationship between both parties and increases loyalty. (Bezerra Barquet et al., 2013.)

Table 4. *The advantages of PSS for customers and companies (Bezerra Barquet et al., 2013)*

Customers	Companies
More customized supply. New functionalities and combinations of products and services to better suit customers' needs. Responsibility for monitoring and end-of-life transferred to the manufacturer. Higher total value delivered to the customer by increasing service elements.	New market opportunities and competitive advantages. Access to information about the product's performance during its use phase. Higher profit margins achieved by providing services instead of products. Strengthening customer relationships increases loyalty.

2.2.1 The types of product-service systems

Traditionally, PSS is divided into three different types, which are product-oriented services (POS), use-oriented services (UOS) and result-oriented services (ROS) (Tukker, 2004). These are presented in Figure 8 with comparison to their relation to the tangible and intangible offering of a company. The company can choose whether to put its emphasis on either creating value through products or through services or somewhere in between those. As can be seen from the figure, the ratio between product and service is not fixed inside a PSS type but alternating. It is also mentioned that the line between what is a product and what is a service is not always clear, as most products need additional services to function and a service cannot exist without a product. (Goedkoop et al., 1999.) It is also noticeable that as moving from POS towards ROS, the product is no longer the core and the emphasis is put more and more on the service (Tukker, 2004).

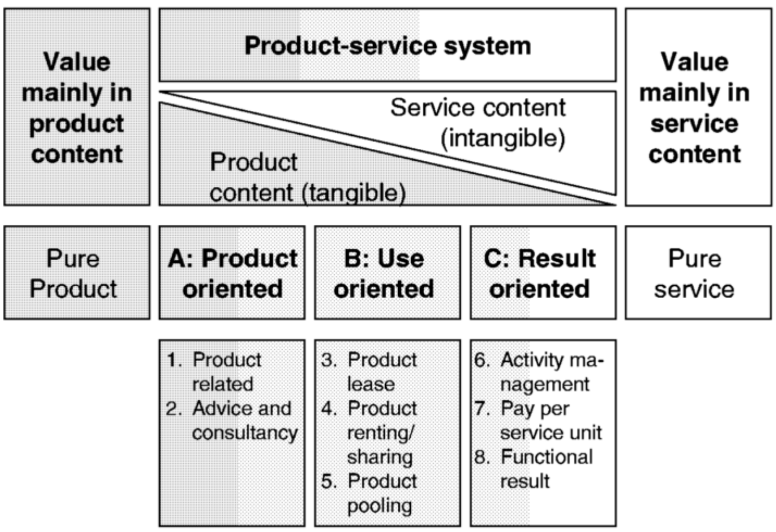

Figure 8. *Types of PSS (Tukker, 2004)*

Product-oriented services consist of the traditional sales of a product, where customer receives the ownership a product when purchasing it and the seller offers additional aftermarket services. These include for example maintenance and repair services, training and consulting. The use of POS can lead to decreasing costs of using a product. (Baines et al., 2007.) POS can be divided into two categories, which are product related service and advice and consultancy. The first means that the provider sells to the customer a product and additional services that are needed during the product's lifecycle. The latter refers to the provider instructing the optimized way to use the product. (Tukker, 2004.)

Use-oriented services are built the opposite way, which means that the manufacturer owns the product and rents or leases it to the customer. This extends the product's life cycle and enables reusing materials. The products are usually made with high quality materials and maintained carefully as the supplier is responsible for the maintenance and repair costs. (Baines et al., 2007.) UOS can be divided into three sub-types. First of these is product leasing, the second is renting and the third is pooling. The difference between these is that in leasing the user has unlimited use of the product, in renting the access to the product is limited and in pooling someone else is using the product at the same time. (Tukker, 2004.)

In result-oriented services the customer receives competences through a product. The manufacturer owns the product while customer only pays for the services the product provides. An example of ROS comes from the office environment, where the manufacturer owns a printer and the customer pays for the sheets printed. (Bezerra Barquet et al., 2013.) ROS is divided into three categories, first of which is activity management. This refers to outsourcing part of the process to a third party. As the result of the outsourced process is controlled, activity management can be seen as being a result-oriented service. The second category is pay per service unit, which refers to the printer-example given earlier. The third category is functional result, in which the provider delivers only a result and is free to choose the method, how the result, for example a pleasant office environment, is delivered to customer. (Tukker, 2004.)

Figure 9 illustrates another way to divide the PSS elements. Comparing to Figure 8 where POS, UOS and ROS created the main categories, in Figure 9 POS is not clearly stated and UOS and ROS are presented only at the lowest level. Investigating the definitions of the elements that form Figure 9, POS can be found in step 1, where the customer is offered either products, services or combination of both. Step 2 consists of the services that are offered to the customer at the time the sales-action is ongoing. This refers to for example assistance in shops and marketing. Step 3 examines the different product use concepts, which here are UOS and ROS. Step 4 consists of maintenance services, which goal is to prolong the lifecycle of the product. Step 5 is called revalorisation services, which refers to the manufacturer offering a service where the product, which is at the end of its lifecycle, is taken back and its parts are either used to build new machines or they are recycled. (Mont, 2002.)

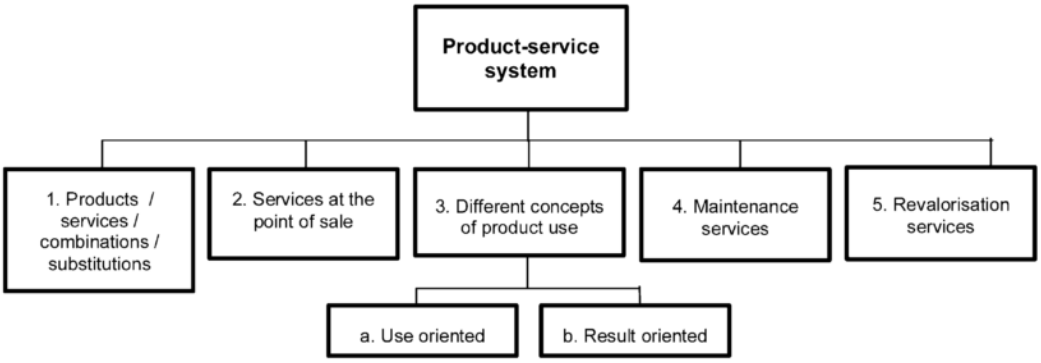

Figure 9. *PSS classifications (Mont, 2002)*

2.2.2 Drivers for adopting product-service system

The goal for adopting PSS is improving business, whether the company is originally product-oriented or service-oriented, but the drivers are different. A product-oriented company adds services into its offering in order to broaden its market area and create more value to its customers. Whereas a service-oriented company adds products to protect the market area it already has gained as services can be relatively simply copied by competitors. A service-oriented company can also aim to create new innovations and/or extend the service itself. At the same time a product-oriented company might be interested in increasing the offer made to customers, since they can also offer for example maintenance and repair services in addition to just providing a machine. (Goedkoop et al., 1999.)

Although purchasing of a PSS can be more expensive to customer than just buying the product, PSS can still bring significant savings to the operation. The total price of a physical product is usually more than just the amount of money given to its manufacturer. The product needs additional resources for its handling and management and it might need space in storage. The purchasing price of the product might be only a fraction of the total cost of the product to the customer. With PSS, the service provider might take care of most of the additional resources needed, which in the end lowers the customer's total cost, even though the PSS might be more expensive than the basic product. (Tukker, 2004.)

PSS can be seen as an alternative to mass production and highly standardized products. The value that customer receives increases when adding service attributes to a product. (Mont, 2002.) Environmental factors are also seen as drives for adopting PSS. With take-backs, refurbishments and recycling the environmental load is decreasing. Also the use of resources reduces as fewer products are manufactured since the ones purchased match the customer's needs better and their lifecycle prolongs. (Baines et al., 2007.)

For customers, PSS offers alternatives that better suit their needs. With leasing or renting, a product that they cannot afford to purchase becomes available. As services are by nature flexible, adding a suitable combination of them to the product creates a PSS that matches with customer's changing needs. (Mont, 2002.)

As adopting PSS requires changes in the organisation, it also enables a convenient platform for making innovations (Mont, 2002). Innovations can occur merely as a consequence of the changes in organisation, as taking in PSS might lead to changes in staff, strategies and organisational structures (Kasperek et al., 2014). It has been in fact noticed that there are four different kinds of innovation types that can be related to PSS. These are product innovation (changes in the objects that are offered), process innovation (changes in the creation and delivery processes), position innovation (changes in the context in which the PSS is presented) and paradigm innovation (changes in the mental states defining what the company does). (Tan, 2010.)

2.2.3 Barriers for adopting product-service system

There also are some valid reasons why a company might choose not to adopt PSS as a way to develop its offering. First, the company might lack the knowledge needed to add a service or product into its portfolio. Some companies have for example strong technical knowledge but at the same time they do not have competences to offer any services. Second, the company might lack the resources to add anything new to its offering. Third, it is also possible that the market area the company is in, does not support a product-service system. It is important to notice that not all companies are interested into combining services and products and not all are capable of doing it in the first place. (Goedkoop et al., 1999.)

A challenge PSS faces is how to translate something abstract into a concrete product. It might be difficult to generate indicators for too vague requests coming from the customer. For example the provider might struggle to determine what needs to be supplied, when the customer asks for quality performance. The issue is challenging for customer too, as they might not always know, did they receive the service they purchased. (Tukker, 2004.)

One of the greatest barriers for adopting PSS is the cultural change it requires. Some customers might not be interested in not owning the product and only paying for its leasing and additional services the use requires. For manufacturers, the shift in the organisation to produce more services than products can cause changes in the resources needed. Changes in job descriptions require money and time, which some companies might not have. Organisations also might not have sufficient experience to start producing PSS instead of traditional products. (Baines et al., 2007.)

Though PSS can bring significant improvements, it can also produce negative side effects as it changes customer's behaviour. Examples mentioned are spending the money saved somewhere else thus increasing the material flow when one of the goals of PSS was to decrease it. As the customer does not own the equipment they use, careless use might occur, since the maintenance and repair is not their responsibility. (Manzini and Vezzoli, 2003.) Also as the production is shifted from manufacturing to producing services, some jobs might be lost (Baines et al., 2007).

2.2.4 The design perspective and alternative processes for adopting product-service system

Figure 10 elaborates the three dimensions of PSS that give the design perspective. These dimensions are actor network, product life phase systems and customer activities. It is important to notice that when creating a PSS, changes in one perspective affect the other two as well as the whole system, which is presented in the middle. This model can be used to analyse how the current products and systems function and how their relations with each other could be strengthened. (Tan, 2010.)

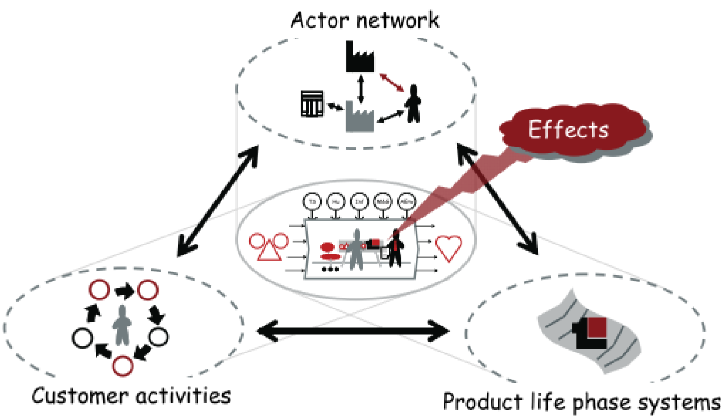

Figure 10. *PSS dimensions (Tan, 2010)*

Figure 11 depicts a framework created to support organisations implementing PSS. The framework consists of three parts, first of which is business context. This means analysing the current business model and its future after PSS is in use. It is also important to recognise both internal and external restrictions in order to optimize the PSS. Although it is possible to create a new business model for PSS, it is recommended to adapt it to the current one in order to compare PSS's performance to the current offering. However, it is also stated that some organisations prefer creating new business areas instead of shifting the focus of an existing one. (Bezerra Barquet et al., 2013.)

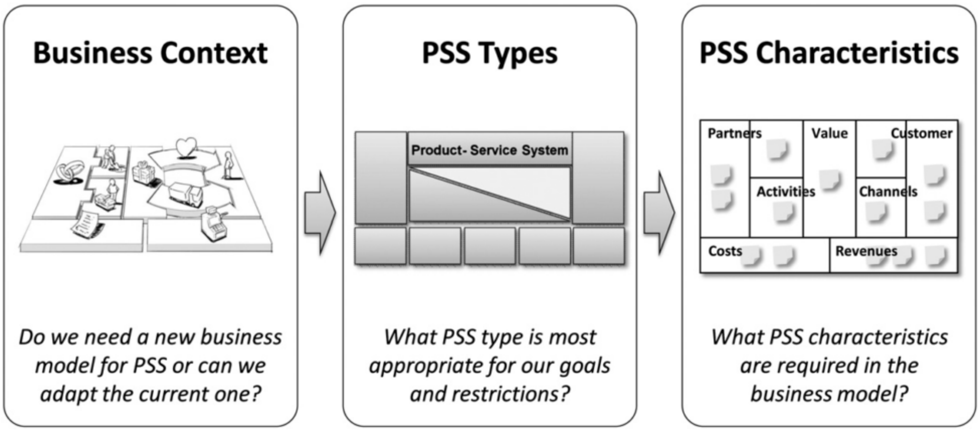

Figure 11. *Framework for adopting PSS (Bezerra Barquet et al., 2013)*

After determining the business context, the appropriate PSS type is selected, which were presented in Figure 8. The final parts studies the PSS characteristics, which looks at the attributes needed in the selected business model. One such attribute is value proposition, which focuses on creating value through the enhancing the satisfaction of the customer. Examples given were lowering the manufacturing costs and decreasing the responsibility of the product throughout its lifecycle. Another attribute is customer relationship, as providing PSS requires co-operation with the customer. Relating to customers, key activities is an attribute that emphasise that a producer should focus on producing activities that the customers find most important rather than putting too much effort to the activities that relate to physical products. Identifying key partners that form a network which support the value creation through products and services is an attribute worth recognizing. (Bezerra Barquet et al., 2013.)

Another process model for representing the development of PSS is presented in Figure 12. The point of reference for the model is an existing product or service, which is used to determine if PSS creates the same or better benefits as the original offering, while increasing the value customer receives. This in fact leads to the centre of this model being the value proposition for each actor being part of PSS. The goal of this model is to identify the changes made to the product as well as the changes made to the production and how the stakeholders can be motivated to take part. (Tan, 2010.)

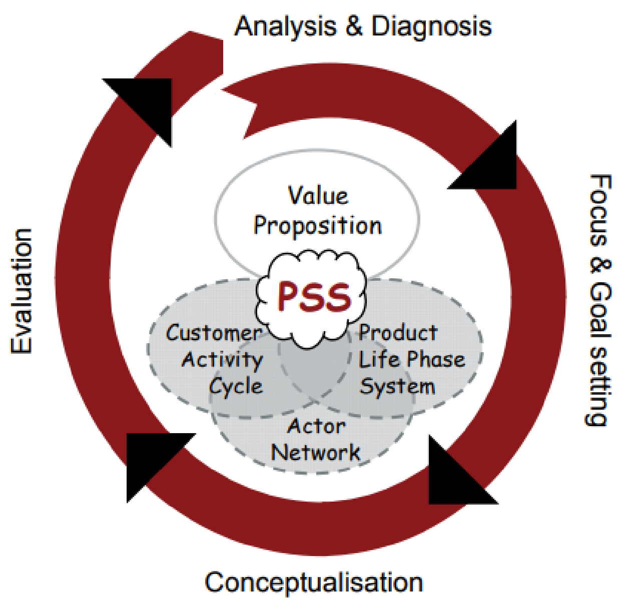

Figure 12. *PSS development (Tan, 2010)*

The first step of the process is analysis and diagnosis. This refers to investigating the existing products and services and the value they create, for example quality, flexibility and risk, before changing them into a PSS. Collecting data from multiple sources create detailed insights for example about product's life cycle and customer's activity. This provides possible scenarios that could be pursued. The second step is focus and goal setting. This refers to focusing the available resources to the design strategy selected. It is important to recognize the degrees of freedom that are available. This means setting the focus on aspects that can be made with current technology and accepting that some effects are not possible to avoid. At the end of this phase, the goals are set, which solutions will be pursued onwards. (Tan, 2010.)

Third step, conceptualisation, describes the suggestions for the products and services that include the most important features of the final offering. Conceptualisation is used to create an overview of the PSS and what is included in it. It also includes risk estimations. It is suggested that a number of different concepts should be created in order to increase the chances of finding the best one. The fourth and final step, evaluation, compares the best concepts created to determine the most suitable solution. It is noted that a perfect solution does not exist. The best possible PSS solution makes improvements possible in several extents, creating increasing value. (Tan, 2010.)

Figure 13 presents yet another process for creating PSS. The process has five steps, starting from defining the needs and goals and ending in evaluation of the created product-service system. This model emphasises the importance of the customer, as each stage has the customer involved or evaluated in one way or another. The model also includes the organisational aspect. In order to make a successful PSS, own organisation must also be studied and some processes need to change to support the PSS. (Tuulaniemi, 2011.)

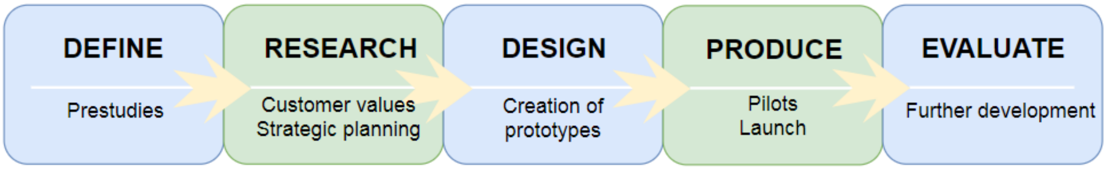

Figure 13. *PSS process (Tuulaniemi, 2011)*

The first step, define, aims to determine the goals for PSS development as well as timetable, budget, resources and target group, whom the PSS will be developed. It is also important to determine organisation's current status and defining the competitive and market states. The goal is to define production challenges and create an understanding of the PSS organisation and its goals. The second step, research, investigates potential customer's hopes and needs as well as needs and goals of the parties who participate the production. Organisation's market position is also researched. The goal is to enlarge the understanding of needs, goals, expectations and values of both customer and own organisation. (Tuulaniemi, 2011.)

Third step, design, aims to create different prototypes of the PSS and tests them with target groups. The critical parts of the PSS are recognized and the solutions developed further. The goal is to develop alternative solutions to design problems and compare these to organisation's goals and customer's needs. Fourth step, produce, includes doing pilots and beta testing and developing the PSS further based on feedback received. At this stage, the PSS is launched. The goal is to deliver the developed PSS to customers for evaluation and create understanding of the resources that are needed to produce PSS. The final step is evaluating, which measures and evaluates the PSS based on customer experiences and further develops it. The goal is to standardize the PSS so that it can be moved to production. (Tuulaniemi, 2011.)

2.2.5 Standardizing a product

Standardizing refers to developing the product or a part of it into a kit that can be duplicated or repeated. The standardized kits can then be sold as such to different customers, which make the service process more efficient and homogenous. The goal of standardization is to design the PSS process so that some or all parts of it can be carried out the same way from one customer to another. This increases productivity and quality. (Jaakkola et al., 2007.) Standardization can also reduce the quantity of manageable parts and increase the production capacity (Baud-Lavigne et al., 2012). The level of standardization can be adjusted, depending on the service that is under development as seen in Figure 14.

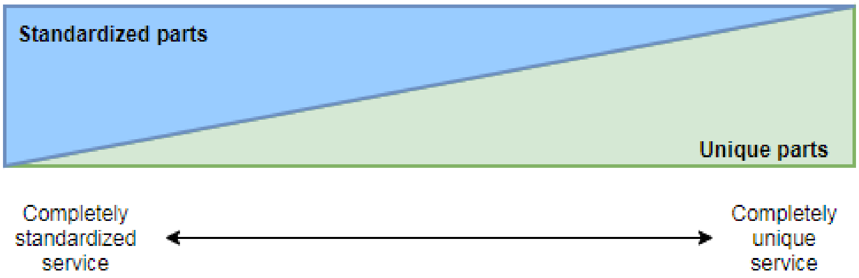

Figure 14. *The levels of standardization (adapted from Jaakkola et al., 2007)*

In most cases, the level of standardization is chosen between the two ends, making some parts of the service standardized and some unique to be chosen case by case. The important aspect to think about when choosing the level of standardization is how much value current level will bring to customer. With complete standardization, there is no room to consider customer's different needs and desires. On the other hand, completely unique service is slow to make and often not cost-effective as everything needs to be planned from scratch each time. It is important to know what level of standardization competitors are using and if customers would appreciate more unique or more productized service. (Jaakkola et al., 2007.)

More standardized product is market oriented and thus more customers are interested in it. Market oriented product does not automatically mean that it does not have any flexibility for customer's needs. (Artz et al., 2010.) Standardized parts can be divided into modules, some of which form the basic service and others can be chosen as additional services if needed. A service that is modular is flexible and cost effective but the parts that are used must be easily combined with each other. (Jaakkola et al., 2007.)

3. RESEARCH METHODS, MATERIAL AND PROPOSAL

The implementation for solving the research problem is based on interviews and benchmarking. This chapter first presents the research methods used for gathering the necessary information. Next, the additional material needed to carry out the implementation is elaborated.

The chapter ends with the proposal to solving the research problem. Based on the material presented in chapter 2, the suitable retrofit process is explained. Next, the plan for implementation of both interviews and benchmarking are discussed. The final part of the section starts with selecting the suitable PSS method from the ones presented in chapter 2. Finally, a theoretical framework for solving the research questions is created and explained.

3.1 Research Methods

This research is implemented to create a model on how to develop a product-system service for the RTG retrofits in Kalmar. In order to do this, information about RTGs and retrofitting must be found inside the target company. The empirical part of this thesis consists of a series of interviews, which were carried out with Kalmar employees. The main method for the interviews to collect data in this thesis is open-ended interview. This means that the interviewer has prepared a set of questions but the contents of the response are unknown (Thibodeaux, 2017).

Open-ended interviews can be divided into three groups based on their structure, which are structured, semi-structured and unstructured interviews (Thibodeaux, 2017). Structured interviews are carried out the same way each time, asking the same questions with the same wording and tone of voice. They are used to gather quantifiable data. In semi-structured interviews, the interviewer has some questions and themes to be covered during the interviewing session. These questions might vary depending on the situation and who is being interviewed. The interviewing session is more like a conversation than a formal meeting. The third method is unstructured interview, which is used to explore a certain area informally. There is no pre-prepared list of questions, only a clear idea of the aspect that should be covered. The information is gathered by letting the interviewee talk freely about the topic. Figure 15 elaborates the different forms of interviews. Structured interviews can be seen as standardized and semi-structured interviews are non-standardized interviewing forms. (Saunders et al., 2009.)

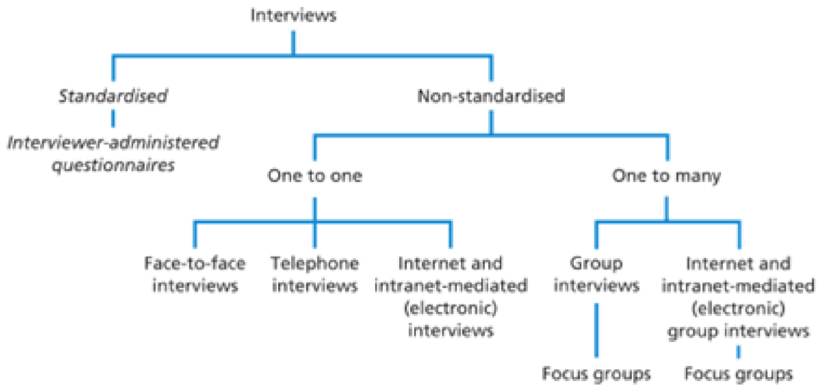

Figure 15. *Interviewing forms (adapted from (Saunders et al., 2009)*

Both semi-structured and unstructured interviews are used in this thesis. Unstructured interviews are used to find the right target people by letting them talk freely about their work and relation to retrofitting. Due to the fact that information is gathered from different departments in Kalmar and from people whose work are very different from one another, structured interview is not a possibility, as each interviewee can't answer the same questions since they might not be related to their work. Thus semi-structured interviews are a better choice as the questions can be customized to match each interviewee's job description.

Interviewees are picked using snowball sampling. This method is used when it is hard to find the target group that should be interviewed (Glen, 2014). Snowball sampling is a non-probability sampling method, where the initial key person is asked to nominate more key people, who will then be asked to nominate more people. This is done until the wanted sample size has been completed or there are no further people left to interview. (Dudovskiy, 2017.) The sampling can also be stopped if going further will lead to unmanageable size of samples. Identifying the first key person is found the main problem. It can also be seen as a challenge that the people identified are too homogeneous, as the respondents might identify only people that are similar to themselves. (Saunders et al., 2009.)

To get more perspectives to retrofitting and PSS, benchmarking was used as one research method. Benchmarking is a process where own organisation, operation or process is compared against other organisations in the same industry or marketplace (Reh, 2017). Usually comparison is done against a competitor that excels in the target area (Suttle, 2017). Benchmarking is divided into three categories, which are internal, competitive and strategic benchmarking. Internal benchmarking shares proven best practices inside the organisation. Competitive benchmarking is used to evaluate own position against other companies in the same industry. Strategic benchmarking goes outside company's own industry and aims to identify and analyse companies that have been highly successful in their own industry. (Stroud, 2017.)

The benchmarking process starts from planning, which includes identifying activities that will be benchmarked. After that the data is collected, for example via researches or interviews. Next, the gathered data must be analysed, which will lead to implementation based on the data collected and analysed. Benchmarking process ends with monitoring, where the new process is evaluated regularly to gain maximum benefits. (Miller, 2018.) Figure 16 explains the benchmarking process.

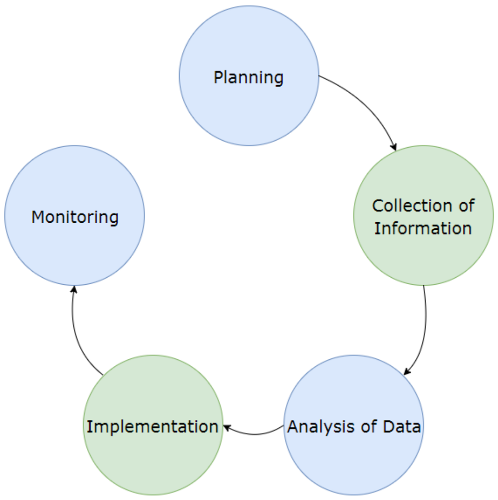

Figure 16. *The benchmarking process (adapted from Miller, 2018)*

In this thesis, benchmarking is used to identify companies that have done retrofitting successfully and learn from them. In addition, knowledge of PSS in retrofitting is seen as a benefit. Both competitive and strategic benchmarking is used to get different points of views on the subject. The data is gathered via interviews.

In addition to interviews and benchmarking, brainstorming is used as a research method. During the writing of this thesis, Kalmar had another master's thesis worker, who was used as a brainstorming partner. Brainstorming is a problem-solving method, which is also used for generating research ideas. There are many different ways to use brainstorming, for example asking for suggestions or defining problems. Each brainstorming session should be recorded, so that they can be reviewed and analysed in order to choose the most suitable ideas. (Saunders et al., 2009.) In this thesis, brainstorming is used as a tool for problem solving and asking suggestions on various perspectives so that the most suitable one could be chosen.

The process of analysing the gathered material can be described with the data - information – knowledge – wisdom pyramid, the DIKW, which is presented at Figure 17. This pyramid represents how the collected data is processed into wisdom. At the base of the pyramid is data, representing all the gathered material needed for the research, which are researched and absorbed by the researcher. As this data is connected together, information is created. With interaction, the information is formatted into knowledge.

Through reflection and joining of the knowledge created, wisdom is achieved. (Vaes, 2013.)

Figure 17. *The DIKW pyramid (Vaes, 2013)*

This thesis process can be analysed through the DIKW pyramid. The material collected for the literature review as well as the interview and benchmarking recordings are data, which is gathered for the thesis. As the articles and books are read and the recordings are written up, information is created from the data. Processing these further, the materials create entities forming the chapters of this thesis and thus knowledge about the topic. Finally, at the end of the thesis, the entities are joined together and reflected, creating wisdom about the thesis topic.

3.2 Research material

This section presents the additional research material, which is needed to carry out the implementation. This material is used in addition to the material presented in chapter 2. The section is divided into two parts. First, the RTG is briefly presented since focus of the thesis is put to developing a PSS to the RTG retrofit.

The section ends with a description of Kalmar's retrofit solution. It was seen vital to explain the current process briefly prior to more detailed description in the implementation part of the thesis. After this section, enough material has been presented in order to move on to the proposal and its implementation.

3.2.1 Rubber-Tyred Gantry Crane

Rubber-tyred gantry crane (RTG) is a mobile gantry crane used for container stacking at terminals. RTGs are used in terminals, where high-capacity stacking and good manoeuvrability are especially important. RTGs are highly flexible as they can be driven to another stack in the terminal, if additional capacity is needed. RTGs have high stacking density and they can interact with road trucks and terminal tractors. (Alho et al., 2017.) Figure 18 presents Kalmar's RTG.

Figure 18. *Kalmar RTG (Kalmar, 2017b)*

RTGs can be automated and they are suitable for the same operations as manually operated RTGs. An AutoRTG can be factory made or automation can be retrofitted later to a manually operated RTG. Automated terminal brings several advantages, including cost savings in terminal operation, increasing efficiency, higher availability and improved occupational safety. Equipment life span is also increased. (Alho et al., 2017.)

3.2.2 RTG retrofitting

Kalmar RTG retrofit has four automation levels, which are:

- 1.1 Remote controlled RTG
- 1.2 Supervised RTG
- 2.1 Semi-Automated RTG
- 2.2 Automated RTG.

Figure 19 presents these levels. The fifth automation level, Fully automated RTG, is under future development. Each automation level can be retrofitted to a manually operated RTG. (Alho et al., 2017.) It is also possible to choose first a lower automation level, for example 1.2, and later retrofit that AutoRTG to a higher level, for example 2.2. However, the level of automation that can be retrofitted to an RTG depends on the existing system, which may create some limitations. Before any retrofitting can be made, the manually operated RTG's electrical system must be upgraded to match the standard requirements set for AutoRTG. Kalmar's retrofitting solution can be implemented on Kalmar's own RTGs as well as RTGs that are manufactured by a third party (Interviewee 2, 2017).

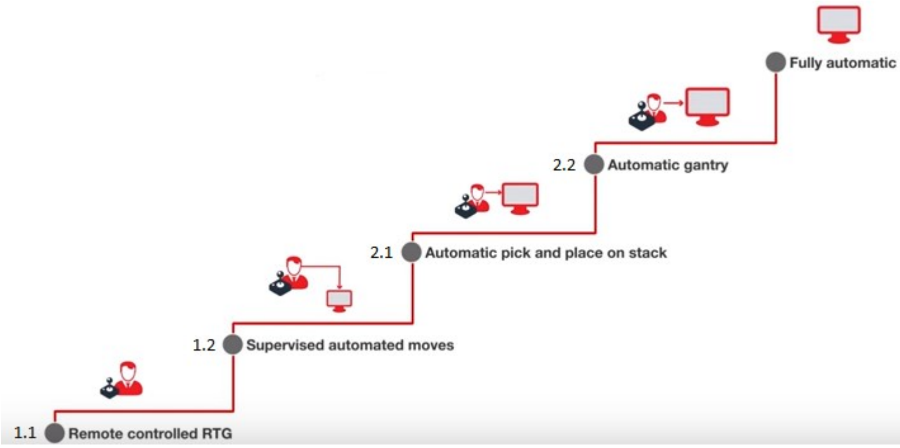

Figure 19. *Kalmar RTG automation levels (adapted from Kalmar, 2017a)*

The first automation level, 1.1 Remote controlled RTG, moves the operator from the crane to an office environment, where one operator can remotely operate several cranes simultaneously. At this point, it is also possible to integrate the crane with terminal operating system (TOS). (Alho et al., 2017.) All the crane moves are done by the operator and automated movements are not possible (Interviewee 2, 2017).

The second automation level, 1.2 Supervised RTG, automates the gantry and trolley movements, which are still supervised by the operator (Alho et al., 2017). Some hoist movements are also possible to automate under supervision. If the crane is not already integrated to TOS, it will be done in this level (Kalmar, 2017a).

In the third automation level, 2.1 Semi-automated RTG, the gantry and trolley movements of the crane are fully automated. The operator remote controls the container operations in the stack and truck lane areas. This level improves the safety in operating area greatly. (Alho et al., 2017.)

In the fourth automation level, 2.2 Automated RTG, all movements are done automatically. The operator can remotely assist in the movements if needed. Picking and placing containers in truck lanes is the only movement that must be done by the operator remotely. The final level fully automatic, is under further development. (Alho et al., 2017.)

3.3 Proposal

This section explains the designs for both the interviews inside Kalmar and the benchmarking to other companies. These sub-sections go through how both of the processes were planned and what kind of interview methods were used. The planned questions are also explained. Based on the literature review on chapter 2, the PSS model chosen for this thesis is introduced in the final sub-section.

Looking at the retrofit process models presented in Figure 4 and Figure 5 it can be noticed that they can both be used when implementing the research topic. First, Figure 4 describes the thesis process itself, as all the materials presented in chapters 2 and 3 complete the steps define and understand. Prior to starting the implementation part of the thesis, it was crucial to determine why retrofitting is done, what is gained from it and most importantly, what an RTG is and how it operates. The next step, decide, here implies to determining the interviewing questions so that they generate needed answers to move on with creating the PSS. The final step, assign, covers the different departments of Kalmar and their responsibilities, when retrofitting an RTG.

Figure 5 deliberates more the actual retrofitting process taking place in Kalmar. The process has four steps, first two being planning and designing. These are completed before the thesis and give the premises and need for the research. The thesis itself takes place in the third step, implementation, where the PSS model is created. The fourth step, performance, takes place after the completion of the thesis, as the evaluation of the created model was listed as future development steps.

As discussed, at the moment there are four possible choices for RTG retrofit with different levels of automation in them. Adding these with the extremes of no or full automation creates in total six different automation levels. For example, Figure 2 can be used to deliberate the ratio between manual and automated operation in Kalmar's case.

3.3.1 The design for interviews

A series of questions were created based on the material found from the literary research and using Kalmar's internal material about retrofits. These questions were related to RTG, retrofitting and PSS. For example, some questions covered the mechanical changes that needed to be made in each retrofitting stage and others covered the general information about retrofitting, its future and competitive position. The questions were prepared so that retrofitting could be looked from different angles and possible problems as well as benefits would come out. One key word in the interviews was standardization, since it was essential for the PSS to know, which parts of the retrofit process were standardized and which had to be custom made with each customer.

The main method chosen for the interviews was semi-structured, which meant that the questions were created more like a checklist for the interviewer rather than a series of questions that can be asked directly. Based on the material about interviewing (Saunders et al., 2009), it was decided that one interview session lasts one hour at most, so that both the interviewer and interviewee wouldn't lose focus. This meant that all of the questions couldn't be covered at one session, which created more rounds of interviews with some key people. For others, the one session was just enough to gather all the information needed. Also, most of the people interviewed were quite busy with their daily work, so it was easier to get them to come to several shorter sessions.

As the target people inside Kalmar worked in various duties in different departments, the same questions could not be used with everyone when interviewing. Thus, a series of questions were created, all relating to the retrofit process and the RTG and only the ones asked were related to the person who was being interviewed. Thus each interview was customized but the base of the interviews were always the same. The idea of a semi-structured interview was that the interviewer had the pre-prepared questions ready and used them as a checklist to get everything covered that were needed. Not all of those were needed to be asked as the interviewees answered some of them before asking. As mentioned before, the atmosphere of the interviews was more like a conversation rather than a stiff meeting.

3.3.2 The design for benchmarking

The benchmarking process started by searching for suitable companies that are doing retrofitting in their own product portfolios. These companies also had developed a PSS for their retrofits some way. The next step was to find suitable people to be interviewed. This was done with the help of colleagues in Kalmar and other contacts, who were working in target companies. With these requirements, contact people from five different companies were found. In the end, one company was seen as a competitor in this business area and they were never approached, as interviewing might have been unethical. It was also highly likely that they would have refused the proposal for an interview. The other four contact people were approached via emails. One of them answered that they do not have a product suitable for this purpose, one was never heard back from and the final two said that they would be happy to participate.

Both selected companies, Valmet Automation and Sandvik Mining and Rock Technology, were located in Tampere area, same as Kalmar, so the benchmarking could be done face-to-face. This was seen as the best way to communicate and collect information. Having a personal contact also made it easier to ask for follow-up questions after the actual benchmarking, if needed.

The questions created for the benchmarking aimed to find out, what kind of retrofits the company uses and how PSS was carried out. The ratio between standardization and customization was also an issue that was discussed thoroughly. Another important subject was customer's participation, if it was needed and at what stages of the process. At this point the sharing of responsibilities between customer and service provider was discussed. In the end, safety issues were covered.

The questions were designed to support a semi-formal interview, which leaves room for the interviewees to talk freely about the topic. In benchmarking, it also allowed the interviewees to choose, what they want to share concerning the question and what is left out of observation. The questions were planned so that decent amount of information could be collected, no matter how much the interviewees chose to tell. During the benchmarking, it was actually noticed that in the other session words were chosen more carefully and the answers were shorter, whereas in the other session the questions were answered longer and more detailed.

3.3.3 Product-service system framework

Figure 8 presented the different PSS types. From their definitions, it can be seen that Kalmar's retrofitting is a product-oriented service. The customer owns the cranes they operate, and Kalmar offers retrofits as a separately sold service. The ratio between product and service contents varies case by case, as customers have purchased different additional services, but the basic principle is always the same.

From the presented PSS models, the one seen in Figure 12 describes the best the current process flow in Kalmar. The four steps in the model are analysis and diagnosis, focus and goal setting, conceptualization and evaluation. This thesis executes step 3, where an overview of the PSS is created and the attributes included are elaborated. The theoretical model includes several different proposals for the PSS as well as risk analysis, which are not discussed in this thesis as they are out its scope.

Based on the theories and models presented in chapter 2, a PSS framework for automation retrofits was created filling the theoretical gap found in developing a PSS for retrofits. This model consists of three parts: parts needed for a certain automation level (A-I), BOMs built from the parts and automation levels, which need one or more BOMs. This model is presented in Figure 20. The framework assumes that each BOM that is needed in a lower automation level is also included in the upper levels as the upper automation levels do not function without all the previous levels' parts.

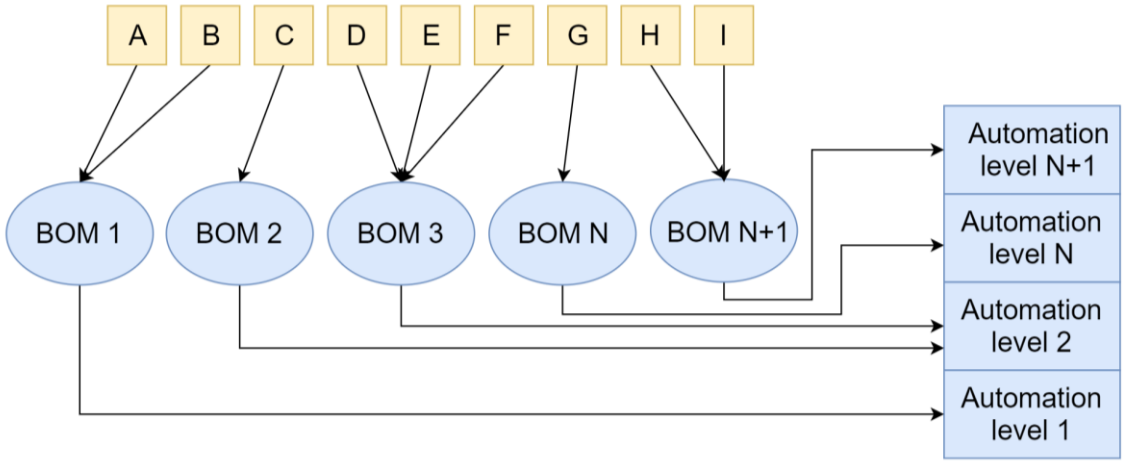

Figure 20. *Framework for developing a PSS for automation retrofits*

In the framework, a BOM is in fact a retrofit-kit needed to create some level of automation to a machine as discussed in chapter 2. These automation levels define the ratio between manual and automated operations as illustrated earlier in for example Figure 2. The BOMs are a vital part of successful PSS since if carefully designed, some of them can be standardized and used as such on different products. The ones that cannot be standardized should be created as generic BOMs with several attributes from which the suitable ones can be chosen based on each case.

The interviews and benchmarking aim to collect enough data so that the framework could be created as their result. The goal is to create such a framework for each of the automation levels separately in order not to make too cramped chart, where the needed information is hard to read. In order not to reveal too detailed information to customers who have not yet chosen to purchase the retrofit-solution, two different sets of frameworks should be created. The first set should be more generic revealing the basic concept and the other detailed, presenting all the needed components for each automation level. The second set is shown to customers after they have signed the contracts of purchasing the retrofit-solution as they are legally bind to keep the business secrets.

4. IMPLEMENTATION

This chapter depicts the implementation of the proposal given in chapter 3. First, the interviewing process inside Kalmar is explained. The section discusses the interviewing process: did the chosen method work, what problems were faced and were the questions answered sufficiently. The results and findings of the interviews are collected at the end of this sub-section. Next, the benchmarking process is discussed, and the results and findings received from the two target companies are looked through. The chapter ends with the description of developing a product-service system and what kind of product was in the end created based on all the material collected.

4.1 Kalmar interviews

This section discusses the interviews, which were carried out in Kalmar. The sessions were held between November and December 2017. The aim was to find out how the retrofitting is done, what is included in the process and what resources are needed. The future strategies for retrofitting were also discussed. In total, 11 people from different departments from Kalmar were interviewed. Follow-up questions were asked during spring 2018 filling the gaps that were found during the analysis of the answers given. Also some information collected needed verification, as inconsistencies appeared.

The first person to be interviewed was the retrofit manager. After that the snowball sampling started to work and in total the interviewees nominated over a dozen names, who were called to be interviewed. Some interviewees nominated people and told what their job description was, others only gave some names without any clues how they were related to the retrofit process. This lead to the use of unstructured interviews, where the interviewees were able to talk freely about their work and what their role was in the retrofit process. Most of these interviews turned out to be useful and led to semi-structured interviews later. However, a few people nominated turned out to be unrelated to this thesis's scope, as retrofit was not that close to their work or it did not affect their work. In the end, all named target people were not called in for an interview, as the sampling size was growing too large to manage and people started to repeat the same things someone had already said. The results and findings of these interviews are deliberated next.

4.1.1 The results and findings of interviewing Kalmar personnel

As mentioned in chapter 2, key element in PSS is to identify the core and support services. Kalmar has recognized the core service in retrofitting being the change from RTG operation process to AutoRTG operation process (Interviewee 1, 2017). The core service can also be how to use existing products in the retrofit business. In the long run, all automation Kalmar has produced during the years should be upgradable. This includes retrofitting other products in Kalmar's portfolio, for example terminal tractors and reachstackers. The key word is in fact reusability, which refers to using the competences Kalmar has to improve the existing products and their operating life. (Interviewee 3, 2017.)

The support services needed to make the core possible are software and mechanical solutions, consulting services and aftermarket support. The goal is to standardize the support services as far as possible, although it can never be done totally, as different customers have varying requests and needs for their crane operation. The standardization should create kits, from which the suitable ones can be chosen in each retrofitting case. Some of these kits can be general ones, including options to choose the most suitable components. Integrating the kits to a machine is always an alternating process, including steps such as parametrizing, testing and optimizing. The execution of these steps depends on crane's type and generation. (Interviewee 1, 2017.)

Continuity and long customer relationships are achieved with support services. In the past, when Kalmar was purely a crane manufacturer, the products had a certain warranty time after which Kalmar did not take much contact with the customer. As things change, Kalmar has evolved from crane manufacturer to a service provider and as such, the long term customer relationships have become the matter to pursue. With support services, for example education, maintenance and support, customers can be kept closer as they might not have the competences themselves to maintenance and update an automated crane. This creates a possibility of offering technical support to the customer. (Interviewee 3, 2017.)

An important aspect mentioned was that retrofitting an RTG is in fact a service product and not a traditional plug and play -product. This is something that might not be clear to customers and should be emphasised. A service product includes the standardized parts, but also customized parts, which will be defined case by case. It is important to remember that some amount of engineering is always needed when discussing about service products (Interviewee 3, 2017.)

As retrofitting is relatively new business area for Kalmar, it has not been advertised much at the moment. The plan is to stay on a low profile until there are some customer references and retrofit has been shaped into a product. In the future, the goal is to retrofit Kalmar's automation into third party manufactured RTGs as well as start retrofitting other products in Kalmar's product portfolio. (Interviewee 3, 2017.) It also was pointed out that as an immature product, it is evident that the process is not yet the best it could be. The product itself is constantly under development, as well as all documentations related to the process. Each time something new is learned, the parts related are changed and made better. The goal is to serve the customers better as well as to improve Kalmar's functions. (Interviewee 1, 2017.)

Kalmar has two major competitors in the RTG business: a Chinese company ZPMC and a Finnish company Konecranes. At the moment, ZPMC is retrofitting third party machines, but Konecranes only does it to its own machines. The market is also changing, as purely automation providers, such as ABB or Siemens, are starting to offer their solutions to the business, mixing the competition even more. Kalmar has strong safety knowledge and as a global provider, they have knowledge of how to function with different kinds of legislations, which are seen as strengths against competitors. Also a strength against the purely automation providers is the deep knowledge of the machine itself, which the competitors do not have. (Interviewee 3, 2017.)

One important aspect mentioned was that the term automation is rather a broad term, which can be understood in more than one way. For one person, automation can mean that a machine works without humans touching it. For another, it means that a process runs automatically, but humans can still be part of it. It should be determined, what automation means so that everyone is on the same level on what is going to happen, if automation is added to a machine. (Interviewee 3, 2017.)

Kalmar RTG retrofit solution

The key point why a manual RTG is retrofitted into an automated one is that it gives the benefits of automation and the flexibility of RTG operations. An RTG moves, as its name refers, on rubber tires, making it possible to move the crane from one stack to another if needed. Kalmar has in its product portfolio another automated crane used for container stacking, called automatic stacking crane, ASC. An ASC moves on rails, so it can only be placed to one stack. Comparing these two crane types, automating an RTG is much smaller process than switching from an RTG to ASC, where the whole terminal needs to be rebuilt. (Interviewee 2, 2017.)

Figure 21 elaborates the automation levels in the RTG retrofit solution. It also describes which crane moves are remote controlled, supervised or automated on each level. Moving from one automation level to another is done with adding components, software and other materials to the crane and terminal. The automation levels are designed to be modular. This means that higher automation levels can be added to the machine just by installing new components and software updates, the previously purchased parts are not taken away. (Interviewee 1, 2017.) This also leads to the fact that buying a higher level automation basically means that the lower ones are added at the same time, as the higher ones does not function without the components included in the lower levels.

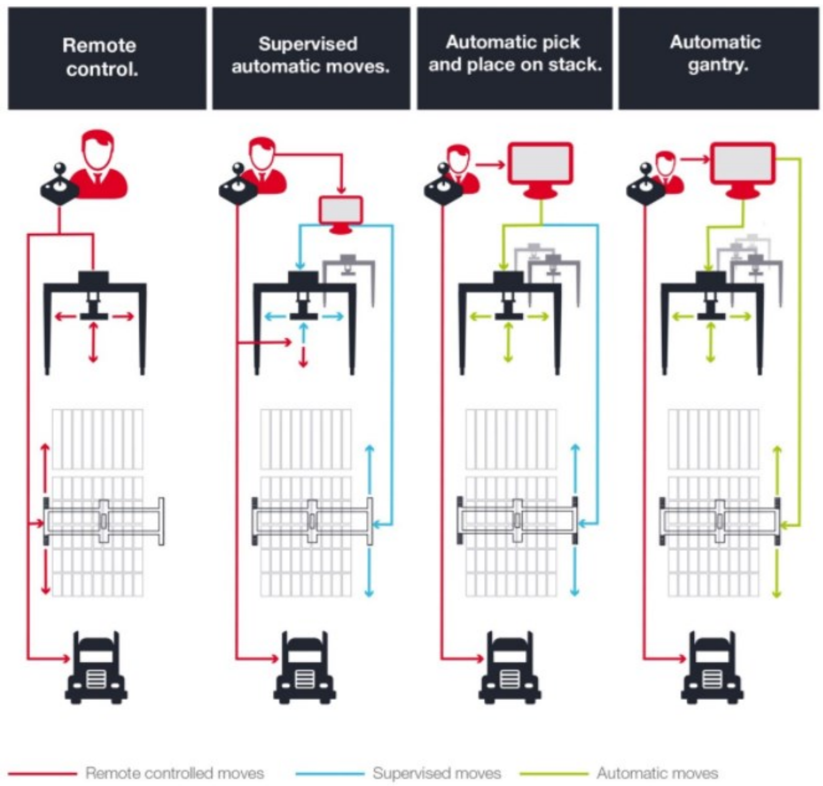

Figure 21. *Retrofit levels (Kalmar, 2017c)*

The simplest level, 1.1 Remote control, does not yet add automation per se, only moves the operator from the crane to a control room. The next level, 1.2 Supervised RTG, already has some automated operations, which are supervised from the control room, so some amount of sensors and other measurement instruments are installed to the crane. At this point the crane also needs to be connected to the terminal operating system, TOS, which is used for operation scheduling. TOS is used to plan which containers need to be moved and where and to give these plans to cranes. In the third level, 2.1 Semi-automated RTG, the trolley can pick and place containers without supervision, which means that at this point the latest, the cranes need to be surrounded with fences to prevent humans entering the area when the cranes are operating. On the highest automation level, 2.2 Automated RTG, the cranes move along the stacking area automatically. The operator is only needed when the containers are picked or placed to a truck. (Interviewee 2, 2017.)

Retrofitting an RTG to level 1.1 first needs a function to keep the crane on its virtual track. As RTG operates on wheels, it cannot drive a totally straight line, but tends to go a little off course from time to time. The crane's PLC software also needs some updating in order to operate the crane from the remote desk. Onboard safety PLC is also installed to make sure that all crucial commands, such as emergency stops, go through a secure line and are received without delays. Also a camera system is needed to get live streaming of the crane's movements to the control room. Naturally, the remote control desk also needs to be obtained. (Interviewee 2, 2017.)

In order to get the communication from the remote desk to the crane reliable, the crane needs sufficient electrification. At the moment, only supported electrification is cable reel, which has optic fibres inside. (Interviewee 2, 2017.) This also means that in order to have any level of automation into a manual RTG, the cable reel is an essential module on the crane, which needs to be installed if it does not exist. (Interviewee 1, 2017).

Level 1.2 needs the integration to TOS, which is done via terminal logistics system, TLS. TLS makes the schedule for the crane, determining which container is moved first and which comes next. Also, a positioning system is added to estimate the position of the crane. In order to move automatically, the crane needs an additional PLC, which works as a steering system giving orders to move the crane. (Interviewee 2, 2017.)

Level 2.1 needs scanners to measure the container and the space around it to make sure that there is enough room to pick and place the container. The trolley also needs to have a measuring system to measure the actual position of the trolley, which can be affected for example by wind. The crane needs to have micro-moving ability in order to correct the small positioning errors. (Interviewee 2, 2017.)

Also needed in 2.1 is the fencing around the stacking area, if it does not already exist. Fencing then again needs an access control -system to the PLC. The access control monitors all the gates on the fences, making sure that if someone goes through a gate, the crane operation shuts down. When the person exits the operating area, the access control gives the crane permission to start operating again. (Interviewee 2, 2017.)

The final automation level, 2.2, adds sensors to monitor possible obstacles that could prevent the crane from driving on the stacking area. Also the tires are covered and connected with an emergency stop -wire to prevent accidents in case someone manages to be inside the fenced area when the crane is operating. (Interviewee 2, 2017.)

Retrofit process

Figure 22 illustrates the RTG operation in a terminal. The figure has three stacks which are all surrounded by fences. The truck lanes are located on either left or right side of the crane. As seen in the figure, the fencing is placed between the stack and truck lane, to isolate them from each other.

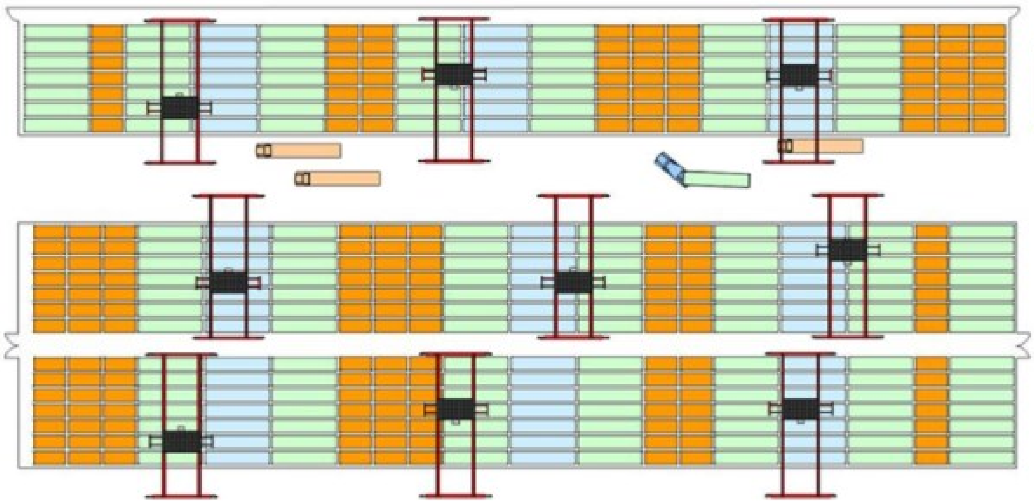

Figure 22. *RTG operation (Kalmar, 2017d)*

When customers approach Kalmar with a question whether their RTG is possible to retrofit, the answer is never immediate yes or no. The crane needs to be inspected and its attributes carefully looked at, to find out the possible solutions. Some cranes can only be retrofitted to lower levels because they lack the attributes needed for the higher levels, which are not profitable to add anymore. Customers might find this confusing at times and it needs to be carefully explained, why something is or is not possible to do. (Interviewee 2, 2017.)

After receiving a lead from customer, the retrofitting process starts from a feasibility study. This is executed with an inquiry form, in which the customer fills the specifics of the crane at hand. These attributes then determine, what kind of kits are needed to fill the gap between manual and automated operations and more importantly, if the crane is possible to be retrofitted at all. (Interviewee 1, 2017.)

An important aspect mentioned are the contracts and other documents which bind both Kalmar and the customer. They should be made in a way that they clearly indicate who is responsible for doing what in order for the project to succeed. There have been cases where the customer might not have understood the importance of some aspect assigned for them, which might then cause delays. (Interviewee 7, 2017.)

The mechanical installations are done all over the crane. Although the phases might be relatively simple to carry out, working around a heavy machine slows the work down. Ideally the mechanical installations take 2 to 3 weeks from start to finish. They are usually done by Kalmar personnel, as a separately sold service. (Interviewee 1, 2017.) The software installations and commissioning also take time, making the total onsite time longer (Interviewee 7, 2017).

The retrofit-kits are designed as engineering specifications, which define the needed components for each project. The installation places need to be defined case by case, as each crane is somehow different than the other. For example, the wiring might run at different places or there might be a beam in a place where there is not one in another crane. Thus, it can only be defined that a component needs to be installed near place X, but the exact place must be looked at on site assessment. (Interviewee 4, 2017.)

Kalmar has created a series of bill of materials (BOM) that include all the components needed to retrofit an automation level. The BOMs give a frame for what parts are needed and what needs to be looked at on the site assessment. In a way, the BOMs create a checklist for the whole process. Retrofitting can never be fully standardized as the installation places of components cannot be set to stone. It always needs some engineering to figure out, how for example a camera can be installed approximately on the right spot. (Interviewee 4, 2017.)

The reason why it is not possible to know all the places for components vary. The RTGs are manufactured by Rainbow-Cargotec Industries Co., Ltd, later referred as RCI, a China-based joint venture company. RCI manufactures all the RTGs sold by Kalmar. RCI have loads of optional components for the cranes, which they might sell separately to the customer. These additional components do not belong to the original drawings, so it is difficult to know where they are located and is there room next to them for retrofit-components. Customers might also do some own installations to the crane and do not inform Kalmar about them, so determining a location to a component is challenging without the site assessment. (Interviewee 4, 2017.)

It was pointed out that the site assessment should always be done before making the final offer to the customer. Besides looking at the places for the components, it should also be looked through that the crane has all the components that customer has said that there is and that they are in a condition that they can be used. It should not be blindly trusted that the documents that are received from customer are up to date. Being more careful can prevent the project from failing. (Interviewee 4, 2017.)

Currently there are discussions about making readiness-kits, which would make it easier to upgrade previously retrofitted machine to an even higher level. For example, if customer is now interested in purchasing level 1.2 retrofit and possibly later upgrade that to level 2.2, the 1.2 project could already be sold with a readiness-kit for 2.2. This kit would include for example wiring or welding, which can be done while doing the other installations needed for 1.2. In the end, the readiness-kit will make the next upgrades easier, when customer is ready for 2.2. The other possibility for the readiness-kit is that when a new crane is being manufactured on the factory, the additional wirings and brackets for retrofit components are done at the same time. This will make the installing of retrofits faster and cheaper in the future. (Interviewee 4, 2017.)

Software

Figure 23 elaborates the system architecture for RTG's software. The highest level is formed by TOS and the remote control, RC, desk. TOS discusses with TLS, terminal logistics system, which creates the operating schedule for cranes. TLS also discusses with onboard vehicle system, VS, and central safety PLC, CS. Central safety PLC is standardized on a product level, all RTGs have the same CS and for example straddle carriers have their own CS, which is a bit different from RTGs. Each block on the terminal have its own CS with alternating parameters, for example how many RTGs operate on same block and how fast they move. CS's task is to receive an order from TOS via TLS, what crane should be moved and when and it then determines the path for the crane, which it should move. (Interviewee 5, 2017.)

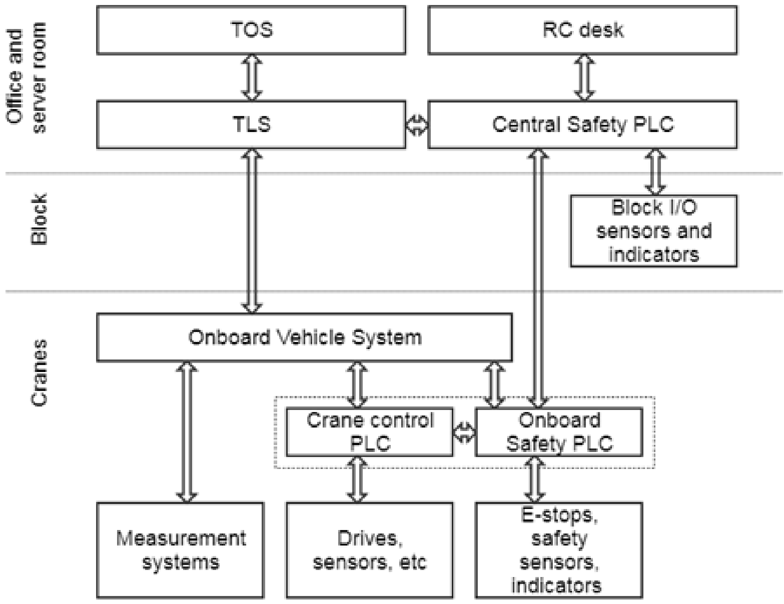

Figure 23. *Architecture of software interfaces (Kalmar, 2017e)*

The lowest level in the architecture is the crane itself and the software it holds. The level starts with VS, which is used to receive tasks from CS. VS then moves the crane accordingly and pick-and-places containers. VS has interfaces with needed measurement systems, for example lasers, and also with the onboard safety PLC. VS can receive commands from the RC desk, so it is vital that all safety related signals, for example the emergency stop command, goes through a safe line. Usually the VS is not modified any other way than adjusting the parameters. There are cases where some customization is needed, if the VS does not implement some function requested by the customer. (Interviewee 5, 2017.)

Crane control PLC is the crane's own control system. It is always a standard part, whether it is in a Kalmar or third party crane. When a crane is being retrofitted, it is assumed that the crane control PLC is functional and capable of performing the tasks given. Onboard safety PLC is responsible of all crane safety related matters. All sensors, indicators, encoders, emergency stops and other components related to safety are connected to this PLC. Basically all manual commands are replaced with the interface between crane control PLC and onboard safety PLC. (Interviewee 5, 2017.)

Controlling a crane needs quite a lot of different signals that need to travel between the operating system and the crane. A challenge noticed in the software is in fact that there are plenty of options in these signals depending on the crane and they all might not behave the same way. For example the crane's speed, in some cranes the speed might be given as absolute number, for example 100 mm/s, and others use percentual speed, for example 50 % of maximum speed. The VS has parameters to these kinds of options, which need to be changed in each case. Through testing, a general set of parameters for each option have been found, but they need to be tested on site each time. (Interviewee 5, 2017.)

In general, the software interfaces are quite highly standardized. The only changes made in each case are the parameters, which depend on the crane and location of components. For example the cameras on the crane need parameters to define the exact location as it might vary in different cranes. The interfaces are almost always the same whether the retrofitting is done to Kalmar or third party machine. The reason for this is to keep the amount of needed interfaces in control. Having different solutions depending on who has manufactured the cranes could in the long run mean that there are too many interfaces to update and control. (Interviewee 5, 2017.)

Infrastructure

Although retrofitting mostly consists of solutions made to the machine and its software, the terminal area must not be forgotten. Infrastructure engineering takes care of the changes made to the operating area. Again, as safety is the most important thing in automation, the goal is to prevent accidents from happening and make the operations as smooth as possible.

Looking at safety, the most important thing in automation is that humans cannot be on the same area as the machine is, when it is in operation. This means that the operation area of an automated crane needs to be surrounded with fences. Retrofit levels 1.1 and 1.2 are still manually operated, although remotely, so the fences are not yet required, only suggested. Moving on to the higher levels, 2.1 and 2.2, the fences become mandatory. (Interviewee 6, 2017.)

The customer is informed about the need of the fences and that they need to be placed prior to the retrofit-installations. Usually only the interface, meaning the access control, sensors, electrical wires and software changes, is provided by Kalmar, to make the operating area secure. The access control is based on the customer's chosen kind of gate. The gate can be manual, which means traditional lock and key -solution, automatic or a safety light curtain. The light curtain is not a recommended solution as it can get disturbed quite easily for example by a plastic bag or a wild animal. It is only used if for some reason manual or automatic gates are not possible to use. The gate is equipped with sensors that inform the central safety PLC that the gates are open so the automated operations must be stopped. Then once the gates are closed the sensors inform the central safety PLC about it and the operation starts again. (Interviewee 6, 2017.)

On level 2.2, the crane moves back and forth the stacking area without supervision. In order to do this according to the safety regulations, a set of transponders are used to give the absolute location of the crane to the operating system. (Interviewee 6, 2017.)

Project delivery

Project delivery, as the name suggests, delivers the sold project to the customer. This is divided into two sections: back office engineering and on site engineering. In back office engineering, the work starts with determining what kind of crane and site is under investigation. This means that the machine drawings need to be obtained, either from the customer or from Kalmar's own databases. This can cause challenges, if the customer does not have the drawings and the crane is not manufactured by Kalmar. (Interviewee 7, 2017.)

Retrofitting is seen as a co-operation -project rather than just buyer and seller -project. Customer's input is needed on various phases. It was mentioned that customer's own mechanics should do the mechanical installations or at least take part in it. This way they learn what changes are made to the machine and know how to maintain it in the future. As retrofitting is an IT project, customer needs to have their own software engineers to do the network changes needed so that the system starts running. It might come as a surprise for the customers, how much their input is needed during the project. (Interviewee 7, 2017.)

The things that usually go well in a RTG project is the infrastructure installations, the RC desk's assembly and other similar things that have been done quite some time already. The BOMs are well designed and every component needed can be seen from them. Also if there is a clear table made illustrating who is responsible for what, things usually get done. The table indicates what Kalmar is doing and what is expected from the customer, for example installing the fences and assigning project manager and other staff members needed. (Interviewee 7, 2017.)

On site engineering starts from installing the mechanical parts and automation equipment. In order to do this, the cranes need to be taken out of operation. As the cranes operate on active terminals, it might be an issue for the customer. This can be overcome by careful scheduling and agreeing which cranes are taken out and when. Another challenge is that the customer needs to arrange a space for the crane where the installations and testing can be done. With terminals that work with high capacity, it might be a challenge to find empty space. The crane needs to be tested and parameters set in place before it can go back to operation so it is crucial to have a testing space. (Interviewee 7, 2017.)

After the mechanical installations are done, the software is installed. Also as safety is important when working with automated moves, an operational hazard analysis is carried out. The customer is involved in this so that they also understand what it needed to make the operation safe for everyone. (Interviewee 7, 2017.)

Commissioning takes place after all the installations have been completed. It can take some time to get everything working as it should, as tuning the parameters and software takes time. All cranes are somehow different so the software does not perform the best possible way when first installed. Commissioning is a co-operative phase, as the operators are asked to take part in it to get for example the camera views set correctly and discuss about the terminal's operator in order to get the process running the way the customer is used to. (Interviewee 7, 2017.)

After commissioning, the cranes are tested. Customer's input is also needed in this phase, as the tests need for example loaded containers. It also needs to be discussed, how the cranes are integrated in their TOS. This is because every terminal operates a bit differently, and they have very specific processes of how containers come into the terminal and when they are recognized. Some processes recognize the containers as they come through the gates, some when the container is under the RTG waiting to be handled. The automated system needs to be set to match the process, so customer needs to be there to explain the process and monitor that the settings are put right. (Interviewee 7, 2017.)

Also the TOS might need to be modified so that it interacts with the cranes. If customers do not have Kalmar's TOS, which is called Navis, they are asked to commission their TOS supplier to do the necessary changes to make the interaction possible. As the cranes are connected to TOS and the interaction tested, it means that the production on the whole terminal is shut down (Interviewee 7, 2017.)

Challenges in retrofitting

As all processes, retrofitting also faces challenges. Some of them are related to the immaturity of the product and will be resolved as more experience is gained. Other challenges might be a bit more complex to solve right away, but recognizing them is the first step towards making improvements.

One of the more complex challenges is that the cranes being retrofitted usually operate on active ports. Taking the cranes out of operation for weeks can slow down the customer's process. Also rush hours at the terminal can cause issues, when the cranes being retrofitted can possibly be needed for operation. It is stated in the contracts that in such a case, when the crane is unavailable but the mechanics are on site ready to install the parts, the customer is billed for the time the mechanics are on standby. This eliminates the loss of income for Kalmar, but can also cause confusion on the customer if they are not aware of the extra expenses. (Interviewee 1, 2017.)

Another challenge discussed was the customer understanding of what retrofitting actually is. Naturally it is partially a mechanical project, as components need to be installed on to the crane. But in the end, retrofitting is more an IT project, as most of the changes to the operation come from changing the software. This might sometimes cause confusion, as customers expect that they are simply buying a set of components that are installed and everything runs smoothly after that. It might come as a surprise that a lot of work on the software needs to be done and customer's help is needed in order to do that. (Interviewee 7, 2017.)

Customer's competences were also mentioned as a challenging factor. There are cases where customer has said that they can for example do the required PLC software changes by themselves and do not purchase that service from Kalmar. The issue comes when the customer's timetable for those changes does not match with Kalmar's or if the true competence for making the required changes is not adequate. (Interviewee 1, 2017.) Customers also might not have much knowledge about automation and its demands. They understand the crane and what is required to keep that in operation, but discussing about PLCs, terminal operating systems and servers might confuse them. If the automation sounds too difficult and complex, the customers are more likely to back out and continue working with their manual cranes. The solution to this is to make the process look more down to earth, that automation is not actually too difficult to build and learn to use. (Interviewee 2, 2017.)

It is important that the project manager customer assigns to the case understands the technology that is going to be installed. Otherwise customer might start questioning why some things are done a certain way and might do their own solutions. This is not ideal, because it can very quickly lead to problems with the commissioning. Also the safety issues are more easily explained if the risks of automation are understood. The fencing and other safety issues might slow down the process a bit and that can frustrate the customer if they do not fully understand, why it is needed. (Interviewee 7, 2017.)

As the retrofit project is always done in co-operation with the customer, language barriers can become an issue. Kalmar's operating language is English and it is said to the customer that a sufficient language level is needed in order for the project to work. Still there have been cases where some instructions get lost in translation and the customers end up doing something different that was intended. (Interviewee 7, 2017.)

Considering the use of resources, the current situation is seen as challenging. Since retrofitting is relatively new concept for Kalmar, it does not yet have that many employees purely working on it. What it means is that the people needed for a retrofit project to happen are assigned to other projects and getting their input might be challenging at times. There has never been a case where the needed resources are not available, but it might have needed some arrangements. (Interviewee 7, 2017.)

As in all departments, in software too the safety regulations are seen as the biggest challenge. They are constantly under discussion, as the system evolves and new cases come in. One thing under discussion is the use of e-stop. In Kalmar's RTGs, there is a special driver for e-stops, which shuts down the crane in a controlled way if needed. Some third party cranes might not have this driver, which leads to the use of a full stop, when e-stop is activated. The full stop might cause some damage to the machine or the running process, which can be slow to fix. It is seen as a challenge, how the e-stop could be done without the risk of breaking the machine. (Interviewee 5, 2017.)

On infrastructure's side, the challenges come from the fact that the equipment used need space from the terminal. The fences, gates and electrical wires need to be installed properly. For example the wires cannot be installed anywhere, but they need to be installed either underground or running along the stacking area's edges. Also the truck lane needs some more room than before the fences, as there need to be room for the driver to open the doors and come out of the vehicle if needed. It should also be considered that adding fences, where there was not one before, can possibly hamper the operation at first, as the people are not used to the fences limiting the working area. (Interviewee 6, 2017.)

Another thing that usually leads to challenges is the access to the terminal itself. In some countries, especially in Africa, terminals are highly bureaucratic, which means that just getting inside the terminal might take hours each day, as all kinds of forms need to be filled. Sometimes the crane that should be retrofitted is still in operation when the work should start, so again there can be hours wasted before the mechanics can get to the machine. It should be agreed with the customer that the cranes are available at the time the retrofitting starts in order to not waste time just sitting and waiting. (Interviewee 7, 2017.)

Benefits of retrofitting

As Kalmar sees it, automating a manual crane brings a lot of benefits. For example, in manual RTG, where the operator must sit in the crane's cabin to operate it, there is a lot of idle time, when the operator is just waiting for a truck to come to be served. The waiting time can be up to 30-50% in a day. (Interviewee 2, 2017.) With remote control, the operator can work with other cranes if there is not work for one. The cranes not in operation can be shut down to save energy. (Interviewee 7, 2017.) Removing the high level of idle time also makes the operation more cost effective. Although automation might not perform the operations as fast as humans, the functions are uniform. This makes the operation smoother and more systematic. (Interviewee 2, 2017.)

Retrofitting improves safety when people are taken out of the stacking area, where they need to avoid cranes, trucks and other working machines (Interviewee 2, 2017). Also climbing the ladders to the crane can cause tripping and other accidents. In some cases, the operation room might not even be inside the terminal area itself, eliminating more excess traffic on site. (Interviewee 7, 2017.)

Remote controlling also brings more interest into the work itself. Driving a manual crane is nowadays not seen as the most tempting job there is, but offering an office environment with a chance to remote control the cranes, the interest rises. It can also draw different kinds of people to the job, as the working environment is better. It was also mentioned that operating a crane with remote control is relatively simple and almost anyone can learn to do that. The crane operator will do the job most efficiently, but in case of urgency, almost anyone can be put to operate and they will manage it just fine. (Interviewee 7, 2017.)

As technology changes, the machines need updating from time to time. Retrofitting is not as big an investment as buying a new automated crane from the factory, but still the benefits of the new technology can be achieved. Retrofitting can also extend the life expectancy of the crane. At the same time the mechanical installations are done, the condition of the whole crane can be checked and the parts can be changed that might fall apart relatively soon. It also brings savings. In some countries cost the labour is not considered expensive, but the operation might not be optimized. Savings can be found when all the cranes work the same way and thus the operation is smoother. (Interviewee 7, 2017.)

4.1.2 Summary of the interviews and suggestions for Kalmar

The interviews created a thorough image of the current state of RTG retrofitting and the strategy for the future. It was noticed that as a relatively young product, there are several challenges met that are worked on and resolved in the future. On the other hand, the image of the final product is very clear and it is already highly standardized.

What was noticed as a significant issue was the level of communication inside Kalmar. During the interviews some inconsistent statements were given about what is added on each automation level. This led to validating the results and confirming the correct statement. A few times interviewees nominated possible next candidates for the interviews that turned out to have very little to do with retrofitting. One suggestion based on the findings of the interviews is in fact that the communication methods should be looked through and made sure that each department has the same knowledge and agrees with each other.

As the communication inside Kalmar is not the best possible, the same can be said of the communication between customers and Kalmar. Some of the named challenges were in fact caused by misunderstandings and too vague expressions. Putting an extra effort in making detailed documents and sheets about the distribution of tasks between Kalmar and the customer has already shown improvements in communication. As a suggestion, this method should be continued and extended to reach all agreements, which are needed in a retrofit process.

Relating to the communication with customers, language barriers were seen an issue causing significant restrainers. When doing business with customers who are known not to have an adequate level of English, the importance of hiring a translator should be emphasized early in the project. Retrofitting is a project that needs close co-operation between Kalmar and the customer in order to succeed, which means that both sides need to understand each other. Using the documentation of the division of work duties might also help clarifying issues that rise when the language barrier is reached, as written text is usually easier to understand than spoken language.

Another noteworthy issue is the time it takes to install and commission a retrofitted RTG. As the cranes operate on active terminals, taking them out of operation for months at a time might cause the customer to lose interest on the project completely. This is an issue that should partially resolve itself when more experiences are gained and the process starts moving forward more smoothly. Still, it should be actively thought of how the process could be eased and the amount of onsite work needed decreased.

Allocating resources to a retrofit-process has been seen as a challenge. The people that are needed to take part in it have other tasks too that might overtake retrofitting. This should partially resolve itself once the business area grows and more employees can be assigned purely to retrofitting duties. Nevertheless, in order for the business area to grow, the resources are already needed. Even though retrofitting is not advertised to customers actively yet, it might be time to start discussing more about it inside Kalmar to raise awareness and interest towards it. That way the resources might become more easily available.

Retrofitting is used to bring the advantages of automation with a reasonable investment. It also helps the existing machinery to stay up to date, when technology changes. Moving the operators from uncomfortable cabins to an office environment makes the job more attractive and helps increasing the production rate. Improving the operational safety in terminals is a significant benefit that is seen in all departments interviewed.

4.2 Implementation of benchmarking

This section covers the benchmarking done in two companies: Valmet Oyj and Sandvik Mining and Rock Technology. Both sessions were held in January 2018. The subsections first present the results and findings from each company separately.

At the end of this section, the findings are put together and factors mentioned in both sessions are highlighted. Both companies are compared to Kalmar to find aspects that could be improved. The section ends with suggestions made for Kalmar that should be paid attention to in the future.

4.2.1 Valmet Oyj

Valmet Oyj, later referred as Valmet, is a global supplier and developer of automation, services and technology for pulp, paper and energy industries. Their market area covers plant improvements, maintenance and spare parts. (Valmet, 2018.) The benchmarking was done to automation business line, which main product is Valmet DNA automation system.

The automation business line in Valmet delivers only software solutions to automation, the machines and equipment are delivered by other business lines. As such, automation business line calls their retrofit-kits as update packages. The cases are never updating a manual operating machine to an automated one, but updating existing automation systems to have new attributes or functions. (Kiviniemi, 2018.)

Valmet's updating process starts by defining the customer's location as it is not always obvious beforehand. After that the system at hand must be thoroughly explored to clarify if the updates are compatible with the existing system. There are cases where the automation suits better to one system than on the other. When the suitable cases are determined, the next step is to figure out the kind of project that needs to be sold to customer in order to get the update up and running. (Kiviniemi, 2018.)

For each customer's system, Valmet creates a life cycle plan. The plan is made based on the information collected during a mill audit, when Valmet's specialists go to the customer's site and find out what kind of system they have. The goal of this plan is to monitor the equipment and their ages to keep on track when something needs to be updated. One example mentioned was that some systems might still have Windows XP in them, which technical support ended years ago. The life cycle plan reminds to update these, as Windows XP is no longer recommended. The plan is done to each component and it creates the updating schedule for the system. Valmet never updates the whole system at once, but smaller parts when needed. (Kiviniemi, 2018.)

One goal of the life cycle plan is to keep the customer informed about the changes and updates that should be done in the future. They might not be included in the original offer of the update, so the customer might need to purchase some of them separately or buy an update package, which includes certain changes. The life cycle plan also helps Valmet, since they do not need to audit the customer's process each time they ask tender for an update project. The plan already tells Valmet what is included in the process and what parts are scheduled next for an update. (Kiviniemi, 2018.)

One more important aspect mentioned was that after an update, usually some things are different. This can raise complaints, which must be answered. Operators want to know why certain actions are done differently and where some commands have disappeared. Being ready to answer why all the changes were made and how the new system is better lowers the resistance of learning to use the new system. Through experience, Valmet also pointed that there should never be a case where the old and new systems are working together and the operator can choose which one to use. This will always lead to case where the operators use only the old system and do not even try to learn the new one. When doing the updates, the old attributes should be disabled. It was also emphasised that when inventing something new, it should be carefully discussed before putting it to use so that the new thing is absolutely better than the old one, not just fancier. (Kiviniemi, 2018.)

After doing the updates, customers are encouraged to make a service contract. Without one, each time a customer needs technical support, it will cost separately and can quickly become more expensive than expected. With different kinds of service contracts customer can ask help a certain amount of times per month from Valmet. Almost all customers have the service contracts, but it was pointed out that there are some cases where the customer chose not to take it. (Kiviniemi, 2018.)

Valmet offers the updates as different packages, depending on what kind of contract the customer has purchased. With a constant update contract, the system is updated according to the life cycle plan. Usually the updates are done during a planned shutdown of the mill, when everything else is also maintained and upgraded. (Kiviniemi, 2018.)

The greatest challenge that Valmet faces is estimating the workload: how much work, time and resources are needed to get the project done. Some systems might be decades old and it is difficult to estimate the amount of work needed to get new technology running in them. It is relatively simple to determine the components and software changes needed, but estimating the time it takes to do all changes is the real challenge. (Kiviniemi, 2018.)

As mentioned, the whole system is never updated at the same time but only the parts that are indicated in the life cycle plan. This creates the next challenge that Valmet has recognized. Mixing different generations' technologies with each other raises the issue of compatibility. This is not unusual but needs to be discussed each time an update is being done, how the components and software work together if they are not the same generation. (Kiviniemi, 2018.)

The customers do not take much part in an update process. In the past customers had their own maintenance and automation departments but nowadays the supplier mostly takes care of those actions too. Customers are only needed to give the timetable for the update. In process automation business, mill stoppages basically determine the time frame, during which the major updates need to be done. The stoppages can last from a couple of days to few months and the supplier needs to be able to deliver the update during that time. Not all updates need a stoppage, some smaller ones can be done while the process is running. Valmet recognises this as a challenge, since customers are the ones who tell when the update needs to happen, and Valmet needs to be able to deliver the update on time. Stoppages can also cause problems if customer decides to move the scheduled stoppage. This creates a challenge of how Valmet should use its resources when one or more customers would like to have their stoppage at the same time and not according to the original timetable. (Kiviniemi, 2018.)

One challenge mentioned is the future development of the product. In the past, product development was only done to new projects, where customer needed some solution, which did not yet exist. These new solutions were created, but it was not thought of that these solutions also need to be updated at some point. It was not really thought about if the solution can be updated and how complicated process it might be. For a time, updating and maintenance was just a thing that the service department tried to cope with. This challenge has been recognized and for a few years now the product development also has been planning how the updates can be done in the future if they create a certain new solution. (Kiviniemi, 2018.)

Valmet reminds that with every update done, there should be something learned for the next time. Collecting information about how the update went through creates knowledge which helps with the next update. Also, in a global organisation, the working methods should be standardized at some level. When projects are done in one country one way and in another country another way, it does not create the best possible efficiency. It was reminded though that it must be understood that some systems cannot be standardized and done the same way each time. Forcing them to work similarly can cause more damage than advantages. (Kiviniemi, 2018.)

Discussing about standardization, it was pointed out that the basic product, Valmet DNA, is always the same, but the applications vary depending on the case at hand. These applications are chosen based on the industry the automation is going to be delivered and on the system the customer has. (Kiviniemi, 2018.)

During the session it was also reminded that the goal of any business is to make money and not fancy solutions. It is always extra value if the solution looks splendid, but it also might cause a lot of work. Concentrating on how the solution looks, and does every piece fit together with the next one, can create a system that is extremely complicated. That kind of system is hard to upkeep and difficult to update in the future. It should always be thought about how the next update is going to be done when making the current solution. (Kiviniemi, 2018.)

One element highlighted was that sometimes it needs to be said no to the customer's requests. When doing the updates, Valmet tries to find entities that are technically, economically and reasonably updatable to keep the updates compatible with the system and to control the workload an update can bring. Customers might ask for a small update to the system, which could make the updates harder in the future. In these cases, it needs to be said that it is not technically possible to update just that requested part but the whole entity in which the requested part belongs to. The bigger picture should always be remembered and not go into too detailed solutions to keep the whole process together. (Kiviniemi, 2018.)

Looking at competitors, Valmet only has a few of those. Both in paper and pulp technology, there is only one big manufacturer competing against Valmet. As such, Valmet does not try to get their automation into a competitor's system. Big mills usually order some of the automation from one provider and some from the other, making the whole mill having partial deliveries from two or more suppliers. (Kiviniemi, 2018.)

Valmet tries to win over customers who use competitor's automation system, but has recognized this extremely challenging. It is expensive to change a working system to another so customers are not usually interested in it if everything has worked well with the previous supplier. If the customer is not satisfied with the support and service received from another supplier, then they might be open to an offer of changing the supplier altogether. This is one of the reasons why Valmet aims to keep the customer close with the support and maintenance contracts. (Kiviniemi, 2018.)

Another way to win a customer from another supplier is if Valmet has to offer some solution that is totally unique and much better than the solution offered by other supplier. Although it was reminded that if an operator has been using one system for example a decade, the resistance of changing to another system that work differently is significant. The supplier must have detailed answers ready, why the automation system they offer is so much better than the one currently on use. There is always resistance for change, but if the arguments are good, the resistance can be won. (Kiviniemi, 2018.)

Cultural issues were also discussed when deliberating service contracts. For example in Japan, the level of politeness is extremely high. It is more a custom that certain services are included in the delivery and customers might not be willing to sign a separate service contract. Considering how the aftermarket services are provided most efficiently is substantial. It is also important to understand that saying “no” is much harder in Japanese than in Western cultures. China was mentioned as an example from another extreme. In China customers might be reluctant to pay for expert services via a remote access if they have experienced that several of their own local people can perform the task with much lower cost. In almost every country there is a local team doing the daily communication and guiding foreign colleagues with proper way of working. (Kiviniemi, 2018.)

Customers are asked feedback regularly by the local offices. Also after each update the aim is to give the customer a report indicating what was updated and why, but it was mentioned that this is not as systematic as it should be. Valmet also sends once a year a survey to the customers to gather experiences. The problem with this is that customers receive all kinds of surveys constantly, so the response rate is not as high as hoped. (Kiviniemi, 2018.)

It should also be remembered that even though competitor has solved a problem in some way, it is not the only possible solution. Valmet receives some amount of questions from customers regarding why their solution works this way when the competitor has made it that way. It is important to be ready to answer those questions and explain why the solution is different. There is no point to make own product look the same as competitor’s product but their differences should be the ones that make the customer more interested. (Kiviniemi, 2018.)

4.2.2 Sandvik Mining and Rock Technology

Sandvik Mining and Rock Technology, later referred as Sandvik, is a mining equipment manufacturer and part of Sandvik Group. Their field being mining and rock excavation, the offering covers service, equipment and technical solutions. (Sandvik, 2018.) The benchmarking was done to the automation business line.

In Sandvik, automation business line has two product families: AutoMine™ and OptiMine™. AutoMine™ retains all factors related to automation from remote to autonomous operation either on single equipment or full fleet. (Sandvik, 2018.) OptiMine™ is an information management and short term operation management tool. Both of these product families have retrofit-kits available in the offering. (Ruokojärvi, 2018.)

Retrofitting has been done in Sandvik for quite some time now. The concept has also been productized carefully in both product families. When productizing a service, Sandvik reminds that it is important to pay attention to what the core business is, the thing that makes the money. After that is defined, the additional support services must be carefully thought about. These support services can be divided into two groups: the necessary evils which the core needs without question and the nice to have attributes, which create additional value. The necessary evils should be priced competitively so that purchasing them won't become an issue. They should also be designed so that they attract attention towards the nice to have attributes. It is also important to recognize the elements, which competitors do not have and the factors that truly create extra value. (Ruokojärvi, 2018.)

The key element highlighted in the benchmarking, was that the most important thing to remember when productizing anything is that things must be easy to buy and easy to sell. This means that customer needs to understand easily, what value the product brings and what they receive when purchasing. For a supplier it means that the product design is carefully made enabling easier sales and delivery processes. (Ruokojärvi, 2018.)

Sandvik emphasizes that a clear description of the product is essential to avoid conflicts and misunderstandings with customer and supplier. The service should be productized so that both sides understand what is involved in the package and what needs to be purchased separately. This also clarifies the responsibilities of the supplier to avoid confusion. (Ruokojärvi, 2018.)

What was also mentioned as a part of successful PSS process, is understanding the customer base. In Sandvik's business area, customers might want to retrofit only a single machine or in other cases the whole fleet is automated. The offering should answer to different customer's needs, which sets a challenge when designing the product. It was pointed out that the customers have a say in how the product is designed, so that the standard product matches with their needs the best way. (Ruokojärvi, 2018.)

As all service products, Sandvik's solution does not simply consist of the retrofit-kits and their standardization. The customers are also taken care of after the installations with different kinds of maintenance and service contracts. These are sold as separate modules linked to the productized service, which retrofitting is a part of. The aftermarket service business has a product called Sanvik365, which is a service and maintenance service consisting of different levels, from which customer can choose the most suitable. (Ruokojärvi, 2018.)

Sandvik also offers installations and implementations of the retrofitting as a separately purchased service. It is also possible for the customer to come in for training, if they want to learn to do some action themselves. However, most customers purchase the service from Sandvik, especially when something is done for the first time. (Ruokojärvi, 2018.)

Concerning PSS process, Sandvik mentions that the process always starts by understanding the following things:

- own business area
- customer's application

- the additional value created
- making things easy to sell and easy to buy. (Ruokojärvi, 2018.)

The notice should also be put to the fact that all things considering the product being created should be looked from both the customer's and supplier's point of view. This eliminates possible confusions and helps in identifying the key elements regarding the product on both sides. It is also essential to remember, that a successful PSS process not only focuses on the project design but also considers how for example sales, production, delivery times, supply chains, software changes, updates and aftermarket services affect the product and its expenses. As discussed, the level of standardization should be planned carefully to eliminate wasting time on duties that are repeatable throughout different projects. On the other hand, it should be bared in mind that there are always some things that cannot be standardized and some things that can be done in several ways, which should be estimated case by case and decided the best actions. (Ruokojärvi, 2018.)

As mentioned in the benchmarking, a successfully productized service always has some level of standardization in it. In Sandvik's case, most of the components, casings, wiring and software are standardized within the same product family. The same retrofit kit can be used in different models of the same product line with only small adjustments. Examples given were varying brackets, cable lengths and place of installation. These support the easy to sell –statement as only a limited number of customized parts are needed, which makes the order processing simpler and faster. (Ruokojärvi, 2018.)

Looking at Kalmar's case, one challenge lies with the customer not fully understanding what they receive when purchasing a retrofit-kit. As Sandvik has done this much longer, their customers already understand what the product consists of. The biggest challenges for Sandvik has been estimating how complicated each retrofitting case will be. Doing aftermarket installations on a previously purchased and used machine is never simple. The case might not only consist of installing new equipment to the machine but also dismounting old, existing instrumentations. Estimating project costs, workload and resources needed before the machine is up and running is a challenge. (Ruokojärvi, 2018.)

One solution to this is that new machines coming from the factory have automation readiness in them. This means that even though the machine might not have automation components installed when it comes out of the factory, there are clear places and installation cut outs ready for them, should the customer have an interest to add them later. This so called plug and play –solution makes the installations easier and faster and also helps making more accurate estimations about the total costs of the project. (Ruokojärvi, 2018.)

Another important resolution Sandvik has made is standardizing the casing, in which all components are placed. Earlier the design was that components were placed all over the machine, making the installation more time consuming and challenging. Relocating them to a single, standard sized casing makes the retrofitting a much smoother process for the mechanics. This solution also facilitates maintenance and service operations. Recently Sandvik has also put a lot of effort towards minimizing the amount of needed components and making clear interfaces to ease the adding of retrofit-kits even more. (Ruokojärvi, 2018.)

One major issue with retrofits is the time it takes to install new components. The machines needing retrofitting are used in active mines and being out of operation means production losses for customer. Sandvik has recognised this and constantly makes an effort to shorten the time needed for installations. Customer's own actions and external factors can influence how smoothly the process goes. One example given was that for safety reasons the mine might have been blocked and the mechanics cannot enter it to do the installations. Other example was that customer might have promised to provide some specific tools for the installations and failed to deliver them on time. Both of these cases lead to installation delays, while the mechanics are already on site ready to start their work. (Ruokojärvi, 2018.)

Currently there is a new concept under development, which aims to form a group of expertise people that travel around the world to customer sites, specializing in installing and implementing the retrofits. Having expertized mechanics retrofitting the machines makes the installation process more efficient and the machine is up and running earlier. The goal of this group is to smoother the installation process and lowering the needed downtime even more. (Ruokojärvi, 2018.)

The group specialised in retrofit installations can also be used to make the implementation at customer's end more uniform. As mentioned in the benchmarking, the level of knowledge about maintenance and installations by Sandvik's own personnel vary from country to country. Depending on the market area, the personnel might be highly trained to do retrofitting whereas in some other area retrofitting is a relatively new term and there is not enough knowledge to perform the process without help. With the expert group, which main task is to travel from site to site around the world, the process gets done the same way every time and with minimal amount of problems. (Ruokojärvi, 2018.)

An important aspect pointed out was that since the machines operate in active mines, retrofitting process affect customer's operation. While the installations take place, the machine at hand needs to be taken out of operation. Doing the installations as quickly as possible mean less downtime and loss of income and therefore gives significant advantage against competitors and additional value to customers. (Ruokojärvi, 2018.)

Looking at the cost of the needed equipment, it was reminded that at some cases, it might actually be more cost effective to deliver optional parts with the retrofit-kit, which the customer might not need. An example was given from the OptiMine^{TM} product family, where a certain positioning device is delivered with two different cables. The same device can be used in both passenger cars and mobile machinery, only difference being the power cable's connector. In this case, it is actually more cost effective to deliver the positioning device with both cables and letting the customer use the one that is needed than to have two alternative kits in the offering, which forces the salespeople always to ask, which connector is needed. Simplified sales process leads to savings and the cost of the additional cable is covered. (Ruokojärvi, 2018.)

Sandvik's retrofit-kits are designed to be upgradable, which means that the level of automation can be increased later with just adding more components and software. The different automation level packages are compatible, where the higher package includes everything that is used in the lower levels. With lower automation levels, some features might be optional, which customer can choose to take but are not required to get the full benefits of that automation level. These options become mandatory when moving on to higher automation levels. In the lower levels, there are two reasons why customer might choose to purchase the optional features. First is that they already know that they want to upgrade the automation level in the future, so they have to add those features at some point anyway. The other reason is that with optional features, the customer can receive additional value, which can be useful even in the lower automation levels. (Ruokojärvi, 2018.)

When receiving the customer lead of a possible retrofitting case, Sandvik offers to audit the target machine as an additional service. The goal of this is to make sure that the machine is in fact possible to retrofit and that there are not any changes made to the original design of the machine, which Sandvik is not aware of. Retrofitting can be sold without the audit, but then customer is responsible if the purchased kit is not compatible with the machine. In practice that almost all customers purchase the audit as a part of the retrofitting process. (Ruokojärvi, 2018.)

Sandvik's vision about retrofitting third party or competitor's machines is clear. As a product family, OptiMine^{TM} is relatively simple to adjust working in any platform. So in these cases it does not matter, who has manufactured the machine in which the kit is being installed. It is not so simple with AutoMine^{TM}. Sandvik has recognized high risks in retrofitting AutoMine^{TM} solutions to a third party machine. This is due to safety reasons, where Sandvik sees that in case of a malfunction, it might be extremely difficult to investigate, whether the fault was caused by automation or the machine itself. This leads to discussion about who is responsible for covering the damages, the party who delivered the machine or the party who delivered the automation. With these kinds of risks, Sandvik has decided to offer AutoMine^{TM} kits only to their own machines. It was suggested that if a supplier like Kalmar tries to do retrofitting into third party machines, the responsibilities as a supplier should be carefully thought about before entering to the market. It should be thoroughly discussed, what are the things where something could go wrong and if a fault happens, how it can be determined who is responsible. (Ruokojärvi, 2018.)

Sandvik encourages having ambitious goals and holding on to them when creating new products. There is always some level of resistance when adopting new way of working, possibly inside own organisation and definitely on customer's organisation. When discussing about automation and automated operations, customer's employees are normally worried about losing their jobs to an autonomous machine. It should be emphasized that this is not always the case. The operators can be moved to new positions within the organisation, which are more meaningful to them and with better working conditions. In time, the operators might not even want to go back to operating the machines manually. (Ruokojärvi, 2018.)

The other thing customers are usually worried about is the rapid development of technology. Customers want to make sure that if they purchase the new system, it is still upgradable and compatible with new improvements for several years so that they do not have to purchase totally new systems and retrofit kits too often. (Ruokojärvi, 2018.)

4.2.3 Summary of the benchmarking and suggestions for Kalmar

Although Valmet and Sandvik operate on different industrial fields and their retrofit solutions are quite different, some similarities can be found. For example, both companies mentioned their biggest challenge being the estimation of resources and especially estimating the workload needed on each case. The key findings on both sessions also were quite similar, both emphasizing that the most important thing is not to make the product too complicated.

Table 5 presents a summary of the benchmarking results. These can be used as guidelines when productizing Kalmar's retrofit solution. They can also be used when developing the RTG retrofit further. The purpose of the benchmarking was to learn from others, how the PSS could be developed for retrofitting and what the most common challenges are. It was also important to hear, what kind of solutions to the challenges other companies have found. These goals were reached.

Table 5. *Summary of the benchmarking results (Kiviniemi, 2018; Ruokojärvi, 2018)*

	Valmet	Sandvik
Main aspect	- The goal of any business is to make money not fancy things	- Making products easy to buy and easy to sell
Greatest challenges in retrofitting	- Estimating the workload and resources - Using different generations' technology in same processes - Being ready to do the updates at the time of stoppage - Product development not thinking about the updates when designing a new product	- Estimating the amount of resources needed - External factors affect installation time - Making the installation as fast as possible
Solutions to challenges	- Collecting feedback from customers after updates - Raising awareness in product development to think about the updates - Learning something from each case	- Having automation readiness in all new equipment - Standardizing the casing and locating all retrofit components inside - Installations done by an expertise group to speed up the installations
Things to remember	- Be ready to answer complaints and questions with sufficient answers - Say 'no' to customer requests if they are not reasonable - Competitors should not be imitated, focus on own doing - Different solution to same problem might not be better, just different - Make sure that each update is truly better than the previous one - Cultural differences in making service contracts	- Look at the product design from both customer's and supplier's viewpoint - The product is more than its design - For customer, the price of retrofitting is more than the bottom line of the offer - Some level of resistance is always expected - Kits with alternative parts might be cost effective in some cases - Have clear vision of distribution of liabilities in third party machines

Based on the benchmarking results, some suggestions can be made for Kalmar that should be looked at when retrofitting. First, the implementation time onsite is significantly longer in Kalmar compared to Sandvik. A strong suggestion is putting effort to making the onsite work shorter, thus decreasing the time the machine is out of operation and increasing customer’s interest towards retrofitting. As seen in Sandvik’s case, this can be done in several ways. Placing most of the needed components inside the same casing and having automation readiness in new machines makes the job easier and faster on site. Also having an experienced team implementing the onsite work makes the job more uniform and faster. These should be inspected in Kalmar to see, if they are possible to implement.

Comparing Kalmar to Valmet, similar issues can be raised. In Valmet, product development has not been considering enough the updates when creating something new. This issue has been resolved by raising awareness in product development. In Kalmar, resource allocation was seen as an issue. One reason for this was that the people participating retrofitting have other assignments too and as retrofitting is not talked about much in Kalmar, the tasks related to it might not be on top of the priority list. Raising awareness of the process and what is its long-term goal could make resources more available.

Both benchmarked companies raised the estimation of time needed to carry out the project as their greatest challenge. This is an issue that Kalmar should also carefully examine. Most of the engineering work can be estimated quite accurately, but the onsite work is another case. As retrofitting is done in close co-operation with the customer and in active terminals, some delays are always possible, which are caused for example by misunderstandings or rush hours in the terminal.

4.3 Developing the product-service system

This section depicts the process where the final output of this thesis was created. By using all the gathered information from the literature review and the results from the interviews and benchmarking, the product-service system could be developed. The product-service system was based on the framework presented earlier in Figure 20.

This section is divided into two parts. First, the preparation phase is discussed, elaborating the designing process of the PSS. Next, the implementation process is explained. The created documents are presented in the appendixes A, B, C and D.

4.3.1 Designing the product-service system

The designing of the PSS started from defining, what exactly the wanted outcome should be. In order to make it easier for the customers to understand, what Kalmar's retrofitting solution means, a clear documentation of each of the components that are needed in one automation level should be created. The outcome should clearly indicate what components are needed to enable certain automation level's operation and where the components are installed.

The level of information was also determined. It was decided that the documents would be generic and describe the basic principles of the retrofitting. These documents could be used when marketing the retrofit-product to the potential customers. The charts would indicate if for example cameras and some sensors are needed and where they are placed. The precise description of the whole system is given after purchasing it.

The reason for creating a generic set of documents is purely to secure the retrofit business. The product needs to be described to a potential customer enough detailed to raise an interest but not all of the information cannot be revealed as there it still the risk that the customer might not purchase the solution from Kalmar and goes to the competitor. It is bad for business if customer takes too detailed documents to competitors.

4.3.2 Implementation of the product-service system

The implementation started with going through all the BOMs that were revealed during the interviews. As BOM is in fact a collection of all the needed components in a certain entity, they have too detailed information for the documents that were under development. Placing all needed screws, washers and cables as well as all cameras, sensors and other equipment into a same chart, would make it too crowded and confusing. That kind of document could only show to the customer an immature product and certainly would not raise an interest. This led to going through all the BOMs component by component and deciding which actually interest the customer and are worth mentioning. When buying a product-service system, no one is really interested how many screws they need to purchase.

After all the obvious components in the BOMs were narrowed out, there were still some components left that needed to be discussed whether or not they should be presented in the documents. For example the warning stickers were under discussion and the position of the signal lights were inspected. As a result, it was decided that the signal lights need to be presented but the warning stickers can be left out since they are quite obvious parts to exist but can be expected not to interest the customer that much in this phase of the project.

After the components were narrowed down into a number that could be placed into the charts reasonably, their locations were determined. This was done in two phases. First, the locations were discussed with a colleague from the retrofit-team. At this point the BOMs were looked at once more and the selected components were verified being the necessary ones for the documents. Second, the RTG in Kalmar’s test site was visited. The crane was inspected and the places for all chosen components were presented. This was done to verify the phase one discussions and to make sure that all important components were chosen to the documents. The visit also made the RTG as an entity more concrete and helped to visualize the retrofit-process to the documents.

The final phase in the implementation was to create the documents. It was decided that each automation level should be presented on its own document in order not to have too much information on one chart. This also separates the automation levels as their own entities and clarifies that they can be sold separately. However, it should be remembered that the higher automation level chart only indicates the new components that come with that level and all the components on the previous levels are also included. Using these documents correctly to support the sales process requires presenting them all from the lowest level to the level that the customer is interested in.

It would have been possible to illustrate all components in one chart and indicate with different colours, what components belong to a certain automation level. This was considered as one option to avoid the issue of showing too many charts. In the end, the focus was put on creating clear and easy to read charts rather than one chart full of information and a higher risk for misunderstandings. After all, the main goal was to simplify the process and make it easier to understand. The created documents can be seen in the appendixes A, B, C and D.

Before finishing the charts, they were verified to be accurate and possible to use in the future. Some changes were made based on feedback received. It should be noted that testing and evaluating are out of this thesis' scope. This means that the charts are used in action later and they are changed after receiving feedback from customers.

5. CONCLUSIONS AND FUTURE RESEARCH

This thesis aimed to develop a product-service system (PSS) for automation retrofits in Kalmar. The work started with a literature review, the goal of which was to define the concepts of retrofitting and PSS and their current states. Besides the literature review, interviewing and benchmarking were used as research methods to gather all the needed material to carry out the final output of this thesis, the PSS model. As a result of this thesis, a set of visual documents were made to represent the retrofitting process and attributes needed to produce it.

This chapter first presents the major findings and results found during the research. The research questions are gone through and their answers are clarified. Next the limitations are elaborated. The chapter ends with discussion about topics for future research.

5.1 Conclusions and Results

This thesis was a research on developing a product-service system for automation retrofits in the container handling field. The literature review aimed to create an image of retrofits, product-service system and the division of duties between humans and automation. The empirical part of the thesis consisted of interviews inside the target company, two benchmarking exercises done to other companies practising retrofitting in their fields of business and the creation of documents illustrating the retrofit process.

The goal of the interviews was to find out the current state of retrofitting in Kalmar, how the process is executed, the future strategies and the challenges the process faces at the moment. The benchmarking aimed to generate understanding on how retrofitting could be carried out. Another goal was to discuss the greatest challenges faced by those, who have done retrofitting longer and have solved the issues that an immature product inevitably faces. From these results, suggestions were made on what kind of changes should be done to Kalmar's own retrofits and what aspects should be looked at when developing the product further.

During the research it was found out that automation retrofit is a field of technology that is not very widely studied. More studies were found about retrofitting in for example building services engineering discussing topics such as how to make buildings more energy-efficient (Asadi et al., 2011; Ma et al., 2012) or survive earthquakes (Nuti and Vanzi, 2003; Ali Khan, 2009). As it turned out, retrofit is assumed a concept that does not need to be defined, but is understood and known already.

Finding a decent amount of relevant studies about automation retrofits turned out to be one of the greatest challenges during the thesis writing process. As the research went onwards, it was decided to put more emphasis on human centered automation than pure retrofitting. This was done for two reasons. First, it was noticed that the ratio between machines and human labour is in fact one of the most important factors to consider when retrofitting. Second, a higher amount of studies, frameworks and process charts were available for generating reliable perceptions.

Based on the literature review and the models presented in chapter 2, it was possible to create a framework for the suggested PSS model. This framework was presented in chapter 3 and was executed in chapter 4. The resulting documents are presented in the appendixes. These documents will be used in the future in Kalmar when discussing retrofits with customers as well as in internal training.

It was found that the vision on retrofits in Kalmar is quite clear, but the execution is incomplete. Some challenges found will resolve themselves as more experience is gathered and retrofit projects sold to customers. Other issues are also related to the immaturity of the product, but should be paid close attention to in order to improve the process. Such issues are communication inside Kalmar as well as with customers, resource allocation and the installation and implementation time it takes to carry out the process on-site.

5.2 Evaluation of research results

The thesis succeeded to answer the research questions set, which are presented next.

1) How to successfully develop a product-service system for automation retrofits based on literature?
2) How the retrofits can be made to look more tangible and how to make it easier for the customers to see the benefits that retrofitting offers?
3) How to create a framework for developing a product-service system for retrofits in general, so that it can be used in the future when launching retrofits for other products?

First, based on the literature review, several different process models were found that could be used when developing PSS. Second, the documents created aimed to make retrofitting more tangible and elaborate that the process flow is not too complicated to execute. This way retrofitting could look more tempting. Third, based on the literature review and the PSS models found, a framework was created for RTG product-service system. This framework can be used in the future when retrofitting other products.

Participation of Kalmar employees from different departments as well as participation of benchmarking companies Valmet and Sandvik, adds reliability and validity of the thesis's results. The research was carried out in co-operation with a wide range of professionals, who argued their opinions reliably and accurately. The high amount of interviews as well as the follow-up conversations validated the data. Some inconsistencies were found during the analysis of the interviews, but due to the careful planning of the structure of the interviews, these contradictions were found and corrected during follow-ups. It would have been possible to interview even more Kalmar personnel, since some nominated candidates were not called in for interviews, but in that case the sampling size would have grown too large to manage. Also it was noticed several times during the interviews that people were repeating aspects that someone had said earlier. Inviting more candidates to the interviews could have ended with receiving no new information. It should also be noted that repeating the same aspects validated them being the most important factors to be considered.

As mentioned in one of the interview results, the resources in Kalmar might not always be easily available. This was noted already when planning the interviewing sessions. Some of the target people were extremely busy with their work. Finding time to arrange face to face meetings required planning schedules sometimes weeks ahead, but realizing this at an early stage made it possible to organize each interview successfully and without interrupting the thesis process.

5.3 Limitations and critical view

The thesis provided a framework for automation retrofit product-service system. Based on conversations with Kalmar retrofit personnel, the documents created from the framework provide needed information and clarify the process. However, there are some limitations related to reliability and validity of the created PSS.

Reliability can be defined as the extent where same results are achieved on repeated trials (Carmines and Woods, 2005). Thus, the reliability of the created PSS cannot be fully estimated as it was not tested in action during the thesis process. Although the model was approved by Kalmar personnel to be accurate, it could not be tested in internal trainings or with customers. Testing could have revealed defects not seen by those employees, who are familiar with the retrofits. Customers and other personnel not familiar with retrofits see the documents from another perspective thus giving valuable feedback. At the same time the reliability of the created framework is relatively high, as it was based on several studies. Increasing the number of studies covered could have resulted in even higher reliability rate.

As mentioned earlier, the interviews provided some inconsistent results. This also leads to the limitation of reliability. Although some inconsistencies were found and the correct information was validated, there is still a chance that not all of them were identified. As the personnel interviewed came from different departments, the questions asked did not always lead to same results. It is important to notice that the goal of the interviews was to collect data from different perspectives and it was a wanted outcome to get results that differ from one another. It still raises the issue of reliability as all gathered data could not be confirmed to be accurate. Increasing the number of interviewees could have resulted in confirming all statements, but was not seen as necessary as all the major factors were discussed by more than one person. The sampling size was also relatively high and the interviews had already started to repeat themselves, which indicated that all necessary factors were covered.

Validity can be assessed via two categories: construct validity and content validity. In construct validity, the outcome is seen as valid if it is consistent with the existing theoretical predictions. (Carmines and Woods, 2005.) As the number of relevant automation retrofit studies is limited, the construct validity of this thesis's outcome is limited in that extent. On the other hand, the constructed framework was based on the process models presented in human centered automation and PSS studies, which results in the outcome being in line with the theoretical predictions presented.

Content validity refers to the outcome reflecting the full domain of the content. This means that the outcome's content is valid if it represents adequately what was supposed to be measured. (Carmines and Woods, 2005.) As all the research questions were answered and the documents created were approved, it can be said that the content of this thesis is valid. However, it should be mentioned again that since the outcome of this thesis was not tested in action, the content validity is limited. Only the customers and Kalmar personnel to be trained can fully confirm the content validity.

5.4 Future Research

Due to the limitations and scope of the thesis as well as the time it takes to carry out a retrofit-process in Kalmar, the created PSS could not be evaluated and adjusted based on feedback. It should be noted that the first created model is hardly ever the best one there is, which leads to the fact that it should be tested and updated. In fact, a recommendation for future studies is to evaluate how successful the created model is and make updates based on feedback gathered from both customers and Kalmar personnel.

The second recommendation is to discuss with customers after each retrofit project in order to find out how the process could be improved. There should be something learnt from each case, as emphasised in the benchmarking. Although Kalmar's own personnel learn by executing the process, customers could bring vital input from the other perspective about issues that should be resolved.

As pointed out in the interviews, Kalmar has plans to expand retrofitting to other products in the product portfolio as well. The created PSS model could be expanded to other products to create continuity. This would also eliminate doing parts of the process twice, which in fact leads to standardizing the PSS. It is recommended to use the created PSS model as a base for further development of the offering.

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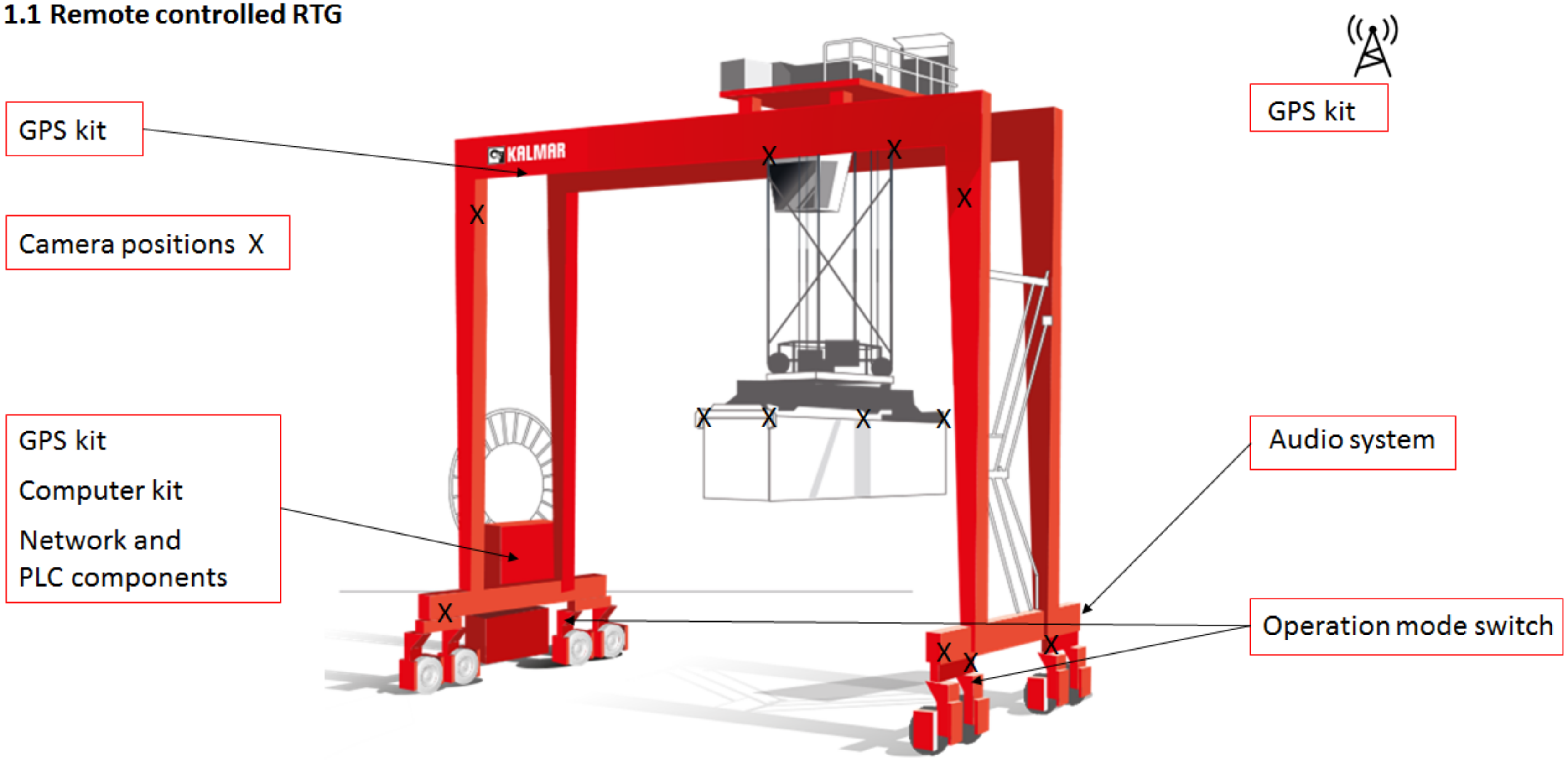
APPENDIX A: REMOTE CONTROLLED RTG

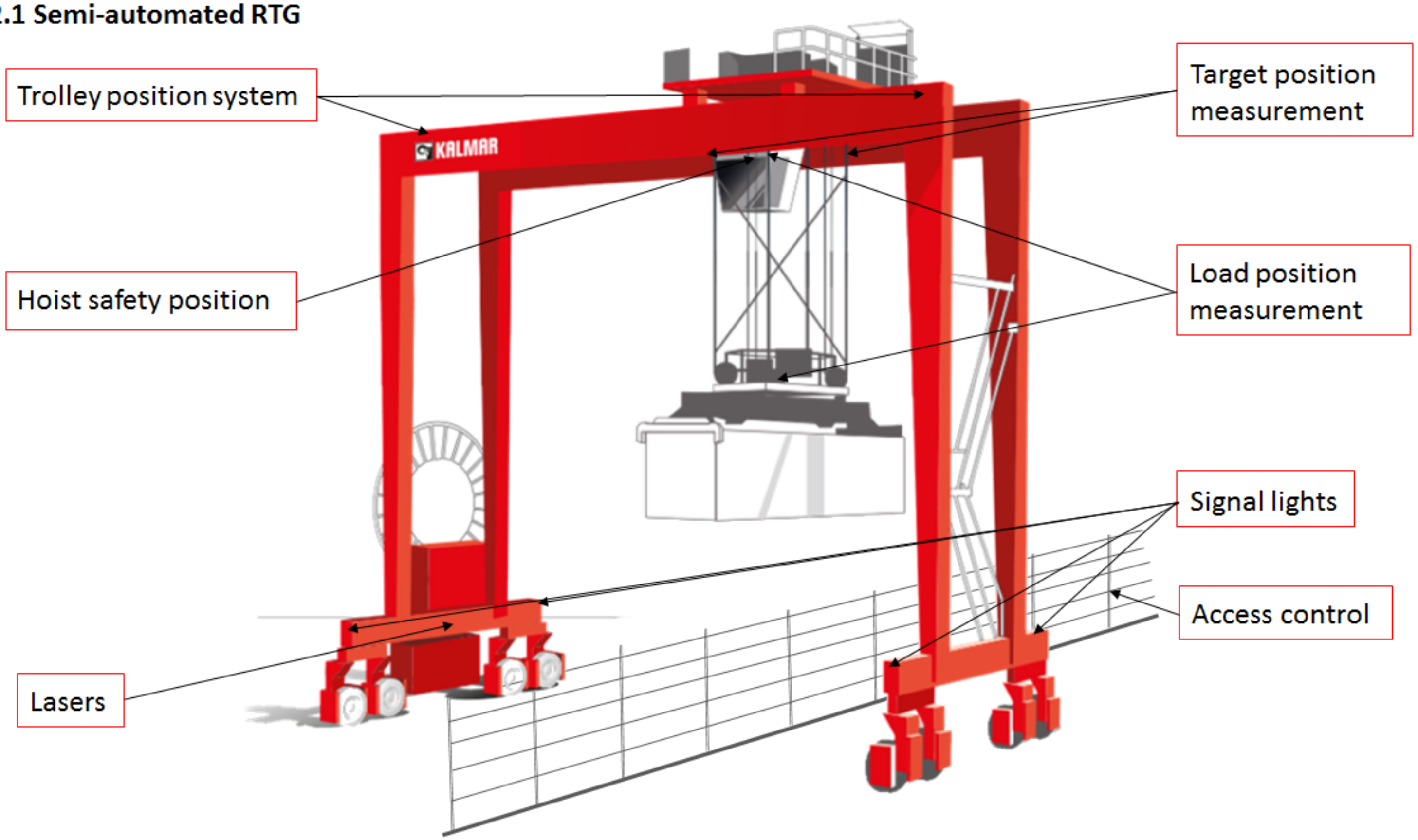
1.1 Remote controlled RTG



APPENDIX B: SUPERVISED RTG

APPENDIX C: SEMI-AUTOMATED RTG

2.1 Semi-automated RTG



APPENDIX D: AUTOMATED RTG

2.2 Automated RTG