Improving the current service design for new Beaver® dredging vessels

Applying servitization methods to create different tiers of service agreements, increasing customer retention

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Master thesis submitted to Delft University of Technology

in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

in **Management of Technology**

Faculty of Technology, Policy and Management

by

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To be defended in public on 17 October 2022

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Summary

The manufacturing world has seen a change from selling manufactured goods to selling a product-service in certain industries. Servitization is the umbrella term for this phenomenon, popularized by Rolls-Royce with their 'Power by the hour' product-service. The main drivers for this servitization transition are from a financial and strategic standpoint. Financially, the added benefit of this servitization of products is the steady stream of income, that is not dependent on the sales of individual products or services. Strategically, it allows the manufacturing company, that has all the technical knowledge of their product, to use that knowledge to improve performance of the customer. While the manufacturer will use their knowledge to keep the equipment in operational state, the customer can focus on their own goals with being relieved of technical issues that are usually not within their area of competence. This also offers a great marketing opportunity, since customers might be inclined to take a technical solution that has maintenance and repairs included, when priced competitively.

This thesis project has set out to answer the following design objective; 'Improving the current service design for new Beaver® dredging vessels'. The Beaver standard product has opportunity for servitization that this project will explore. The result is a service design, based on relevant requirements and available resources. However, before the details are analysed, let us take a look at the methodology.

Methodology for designing an improved service

This project had as a deliverable, a new service design. The goal for this service would be to increase retention rate for customer after their initial purchase. Additionally, recommendations and a path towards implementation are also given. Due to these deliverables the next design process has been used, shown in figure 1. It shows the stages that are taken in this project. Each of these design aspects has either sub-research questions or sub-design questions attached to it. These questions have been the guiding path during this project. By answering the sub-research questions, information and knowledge on the most important processes, infrastructure and stakeholders has been obtained.

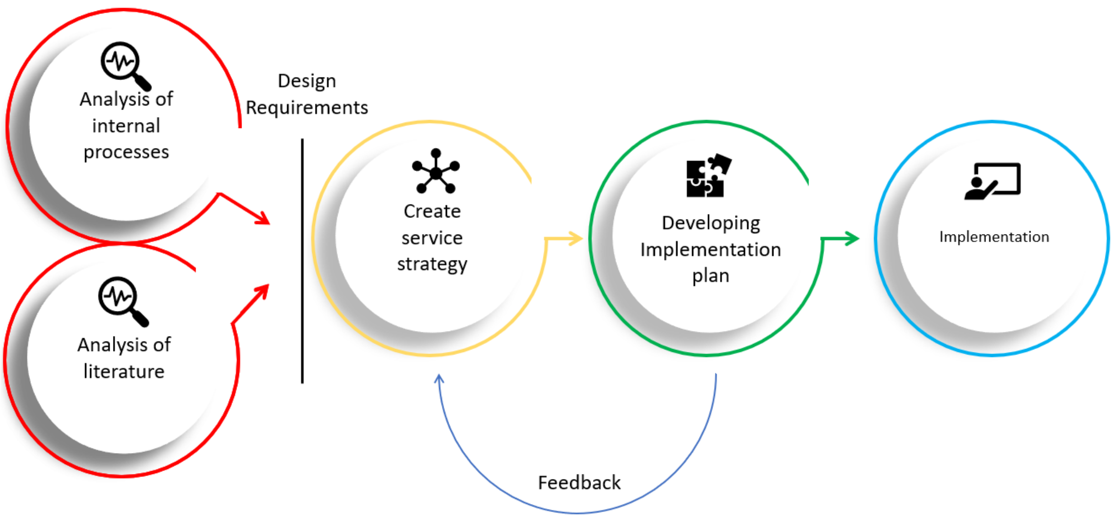

Figure 1: Design process, inspired by (Tschimmel, 2012) and (Li et al., 2020)

The initial round of literature research showed the state of the art regarding servitization. This research has been used to compare the current processes that Royal IHC used against the state of the art in each sector. Whenever a difference between state of the art and actual processes appeared, it has been noted as an opportunity for improvement.

Analysis of internal processes and stakeholders regarding the service program

In this thesis, a number of sub-research questions have been answered, mostly to uncover the actual state of processes, stakeholders, and the opportunities in them. This analysis of internal processes gave insights to opportunities in existing processes and opened the door towards improvements. This knowledge has been used to initiate the design process.

Design process

After conducting the research into the inner workings of the relevant processes and stakeholders within Royal IHC, the design process has been started. First of all, the main design activity is defined as follows;

Design activity: Create a service design that enables Royal IHC to stay the preferred service supplier after the initial sale of a Beaver vessel.

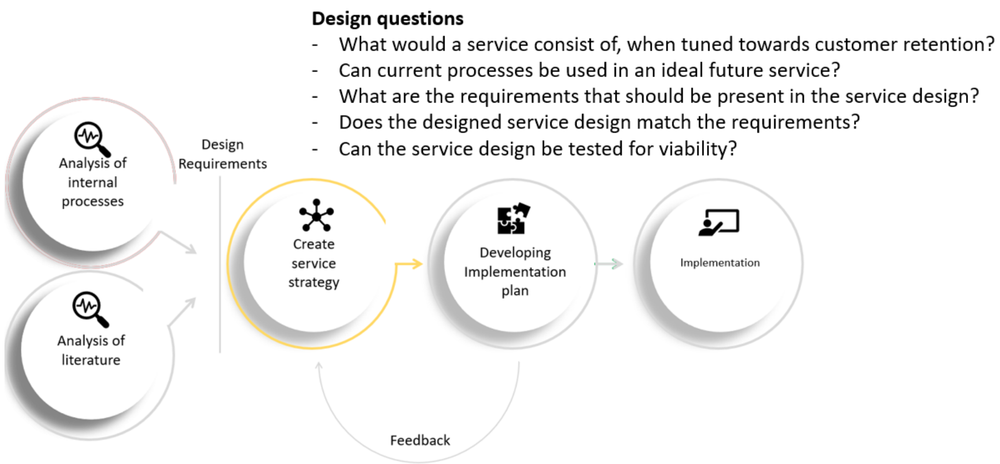

Figure 2: Design component of the project, shown with the main design questions.

This main design activity has sub-design questions that help create a design that is underpinned with academical methods. These questions can be seen in figure 2.

First of all, since the project uses the current service as a starting point, it is important to look at those processes and how they can be translated into a new service design. This design question uses the state of the art literature and the information that the research questions have provided. The knowledge of the processes and stakeholders, relevant historical data, insights in more efficient service processes, and customer feedback. These are all relevant in order to transform the current service into a service that would better fit the goals of Royal IHC.

Before an initial service design can be constructed, the requirements for such a design should be listed and confirmed, as indicated by the third design question. In this case, the requirements are shown in table 1. Additionally, it is indicated if it is a technical or functional requirement, and the stakeholders that confirm the importance of the requirement are listed.

Table 1: Requirements, including the type and those whom confirmed them

MoSCoW	Technical of functional	Requirements	Origin of requirement	Referrenced	Expert statements
Must have	Technical	The parts on the standard spare part list should be classified in such a way that communication to the customer and communication internally is clear	Analysis of internal processes	Managers/supervisor/Sales officer	"Having different terms for the same parts is confusing to both employees as wel as customers."
Should have	Technical	Create customizability within the standard spare part package to account for environmental operating conditions	Analysis of internal processes	Maintenance manager/Supervisor	"It is not logical to sell a tailor made dredging solution to a customer and then use a standard spare part packahe withpout regard for circumstances."
Must have	Functional	The new service should have different tiers of service, in order to fill the need of each customer	Company requirement	Supervisor	
Must have	Technical	The improvements should come from experience and knowledge already within Royal IHC	Analysis of internal processes	Supervisor/DAS	"Due to the financial situation of the company, improvements from existing processes are preferred over heavy investment of resources."
Must have	Functional	The new service design should retain customers for future service requests	Literature and company requirement	Supervisor/literature (Ranaweera & Prabhm (2003)	
Must have	Functional	The new service should increase satisfaction for all customers	Company requirement	Supervisor/Author/DAS	"Our customer are very different and range from megacompanies to beginning dredgers. It is important to find a solution that works for all out customers and not just the extremes."
Should have	Functional	A process should be in place that monitors customer satisfaction and feedback in order to improve the service	Analysis of internal processes	Author/Supervisor	"A feedback loop would allow for continous improvement of the service design over time"
Must have	Functional	Transition from a passive, reactive service, towards a proactive service design	Literature and internal conversations	Author/DAS/Literature (Lenka et al. (2017))	"Taking a more active role in the support of our customer will eventually lead to increased customer retention, if the service quality stays high"
Must have	Functional	The new service design should have a more complete operation monitoring in place for customer that desire it	Literature and Analysis of internal processes	Author/Supervisor/Literature (Naik et al. (2020)), (Martin-Pena et al. (2020))	
Should have	Technical	The service design should be able to turn a profit	Analysis of internal processes	Supervisor/Author	The PMG has the final word on pricing, we essentially just provide a suggestion on content and pricing of the service.
Won't have	Functional	Performance based contracts as a standard part of the service	Analysis of internal processes	Maintenance manager/Author	
Won't have	Technical	Full predictive maintenance integration in the service design	Analysis of internal processes	Maintenance manager/Author	
Won't have	Functional	Full service support for existing vessels	Project limitation due to scoping	Author	

Lastly, according to design question five, the design should be tested to evaluate the validity of the design. Since this new service design is build on the existing service, the improvements should be tested for feasibility. Most of the changes to the design are bringing together stakeholders in order to create more optimized processes and reduce miscommunication. However, there is also a new process proposed. The standard maintenance package could provide the partnership with the customer that pushes them towards Royal IHC as a recurring customer. The package is a service in which Royal IHC will execute all planned maintenance for a Beaver vessel.

To validate this part of the service, a comparison with a similar program in Jordan has been done. This Jordan project also has Beaver vessel of which they perform all maintenance, including the planned maintenance. The performance of these vessel is measured in up-time, of which 92% has been reached during the project. This indicates that under the right circumstances, Royal IHC has the ability to perform a standard maintenance service for a customer.

The service design tiers

The new service design is, as stated by a requirement from Royal IHC management, tiered. In figure 3 the services within each tier are shown. The bronze package is comparable to the service that customers have at the moment. It is an initial spare part package with their vessel and for further help they have to reach out to Royal IHC. The silver package adds operations monitoring and the standard maintenance part package to that. The gold package provides everything Royal IHC can offer regarding service. It combines on-site monitoring with operation monitoring to get all available information to both the customer and Royal IHC. With this information, Royal IHC can become more proactive towards the customer by offering vessel specific upgrades, training or maintenance increasing efficiency for the customer.

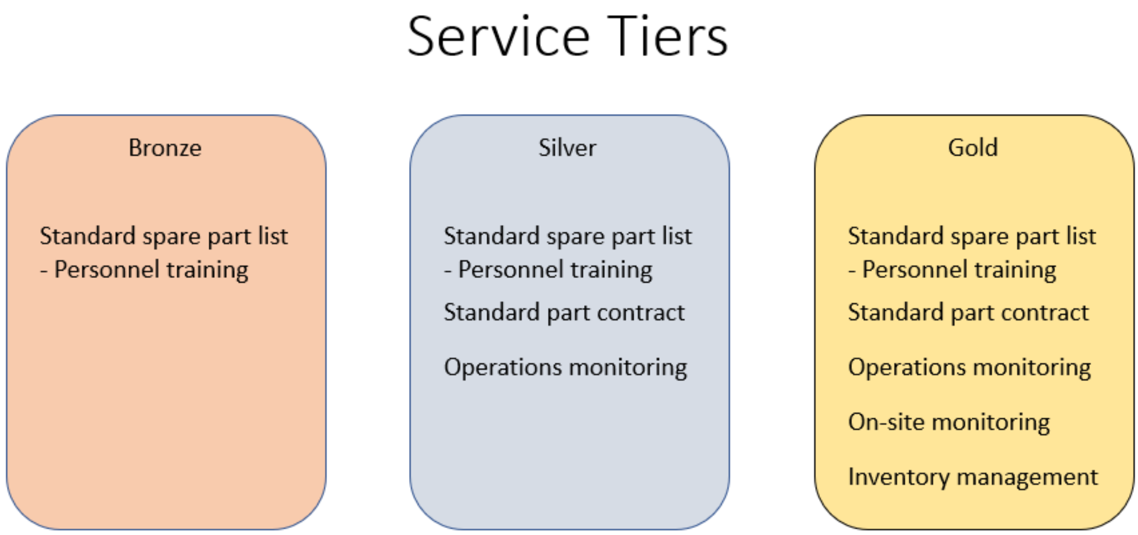

Figure 3: Different levels of service agreements within the service design.

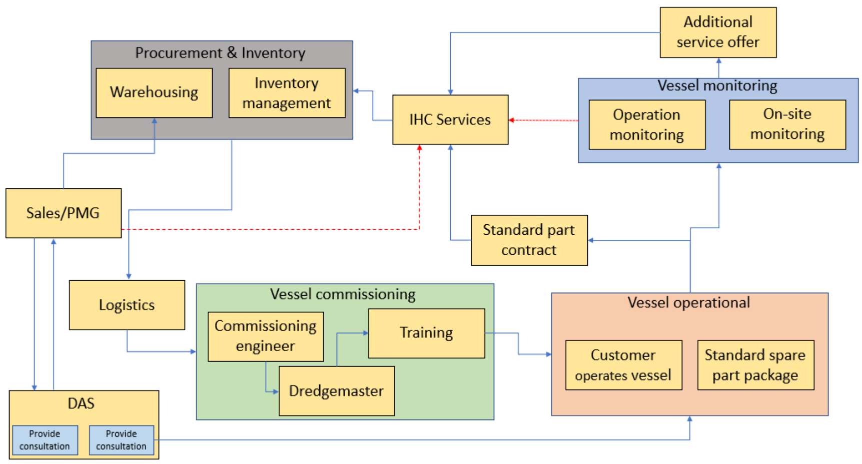

Figure 4: The internal service process that would enable the service design.

Figure 4 indicates the new process flow that makes sure that the service offered by the different tiers can be carried out. The blue lines indicate the flow of processes and the arrows indicate the direction, There are also extra lines of communication added in red. Most importantly are the changes to including Dredging Advisory Services (DAS), vessel monitoring and the standard maintenance parts contract. The most important stakeholders are mentioned and a plan towards implementation is offered.

There are also very promising initiatives towards the future that have not been included in this design. The reason is that this design can be implemented without the need for massive resource investment. The initiatives are listed in the recommendations due to their potential impact and opportunity. However due to the fact that they are not fully developed or operational, they are not included.

Conclusion

Concluding, the opportunity to transform the service design for new Beaver vessels is to capture value by increasing the amount of recurring customers for additional service. The Jordan project has shown that Royal IHC has the competences to adequately perform planned maintenance for customers. By enhancing the technical feedback with operational- and physical monitoring Royal IHC can gain the ability more accurately match operational profiles to maintenance needs. This new design connects both parts of monitoring in order to enhance the information that can be extracted from it. This would allow Royal IHC to become proactive in the service needs of their customers, instead of the reactive stance it has now.

By being a proactive partner to our customers, Royal IHC can show their experience, technical innovation, and product knowledge. These aspects can, in turn, prove to our customer that Royal IHC is a strong partner that actively engages in making their operation a success.

Preface

You will find the thesis "Improving the current service design for new Beaver® dredging vessels", before you. This project has set out to create a service design in the dredging market for non-propelled vessels. Simultaneously, this thesis is my graduation from the TU Delft. For the past two years, I have studied at the Technology, Policy and Management faculty in order to get my masters degree in Management of Technology. Commissioned by Royal IHC, from February till October I have been busy with researching and writing this thesis before you.

This project began after a brainstorm session with my company supervisor, Joost Haagsma. We narrowed the subject down to the design question presented on the first page. At the end of this project, a service design has been created. During this thesis, my supervisors from the university, Marcel Ludema and Marijn Janssen, have provided guidance and feedback. They were always ready to answer questions and help me get forward with the project.

I would like to take this moment to thank my supervisors for their input and assistance during this thesis. I would also like to thank everyone within Royal IHC that I have interacted with during my time here.

I would also like to thank my friends, colleagues and fellow students for sharing their own experiences and helping me along my journey. My girlfriend has been very supportive and was able to help me with some coding issues during this thesis. Lastly, I want to thank my parents and brothers. It was not the easiest of times, but we managed to come out stronger and for that, I am grateful. I hope you will enjoy reading this thesis.

Daan Seegers

Delft, 12 October 2022

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Contents

1 Introduction

How can companies improve maintenance service towards customers? It is a question many companies ask themselves, and it often leads to a multi-variable equation. Across many industries maintenance service runs into problems, because maintenance can be unpredictable. Globalisation adds a logistic challenge and loss of expertise and know-how can result in a difficulty to maintain older products. Maintenance service also has a customer side, which can create an extra layer of complexity. However, in more controlled environments, opportunities lie in optimization of inventory or logistic support.

In the maritime industry complication can arise due to the geographical aspect. Vessels can move all over the world, which can create logistical problems in case of maintenance (Mouschoutzi & Ponis, 2022). In their review, Mouschoutzi & Ponis looked at the maintenance service structure in the industry as a whole and came up with figure 5. There is a multi-echelon structure to it, which indicates the aforementioned complexity due to multiple stakeholders.

In parallel service industries, like aviation, construction or automotive, maintenance service contracts are based on performance. In these capital intensive industries, availability based contracts are a successful type of service contract (Eruguz et al., 2017)(Horenbeek & Jordan, 2012). This type of performance-based contract gives companies opportunities, but it comes with its own challenges. Maintenance service logistics is a well researched subject, however there is still much to be understood about the implementation of certain principles in industries.

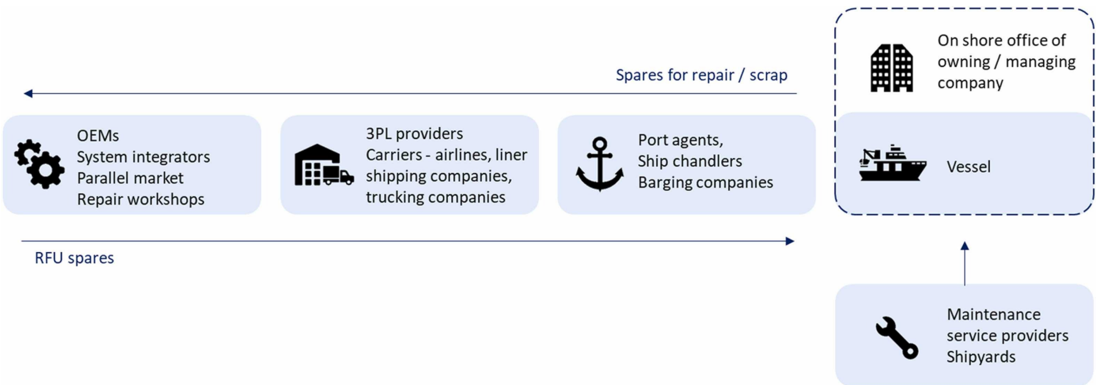

Figure 5: Maritime maintenance ecosystem (Mouschoutzi & Ponis, 2022)

1.1 Scientific field

(Vandermerwe & Rada, 1988) already acknowledged the increasing importance of services in manufacturing firms almost thirty-five years ago. Since then, servitization has been studied by researchers from different backgrounds. Most of whom have accepted the term "servitization" (Vandermerwe & Rada, 1988) (Baines et al., 2013). However, terms like "service-driven manufacturing" (Kindstrom & Kowalkowski, 2014), "service infusion" (Eloranta & Turunen, 2016) and "service transition" (Fang et al., 2008). These are different terms for the same concept that Vandermerwe acknowledged all those years ago.

Servitization is a transitional process where the importance of service increases relative to the importance of the products themselves (Vandermerwe & Rada, 1988). The implementation of servitization has led to what researcher named the "service-paradox". This happens when investments into servitization by manufacturing firms do not lead to increasing revenue, but to increasing costs and lower profit margins (Gebauer et al., 2005). This is one of the challenges that manufacturing companies face in this transitional process.

One major driver for servitization is the development in Internet of Things (IoT) (Lightfoot et al., 2011). Internet of Things is a concept where a network of physical objects is being monitored using sensors and software to connect and exchange data with other devices and systems over the internet. Kevin Ashton coined the term "Internet of Things" back in 1999, in a presentation at PG (Ashton et al., 2009). The increased availability of information that IoT has offered, opened the door for better service products (Naik et al., 2020).

Servitization can be viewed as a degree of integration, in which three levels can be identified (van Schaik, 2016), as seen in figure 6. In these levels, the base servitization is defined as being able to provide spare parts and repairs to customers. Intermediate servitization, the second level, will add continuous after-sales services, like remote monitoring or spare part packages. Advanced servitization changes the deliverable. Instead of providing an initial product and additional products or services, the product is offered as a service. This requires strong contractual agreements and a shift in focus from the product manufacturer towards creating a product-service (EXOR, 2021). In this product-service, the outcome is capability based (Baines et al., 2013). The compensation for such advanced service would not be transactional for goods or services sold, like the other two levels. These advanced servitization models often rely on revenue-through-use, lease agreements, or risk & revenue sharing contracts (Baines et al., 2013).

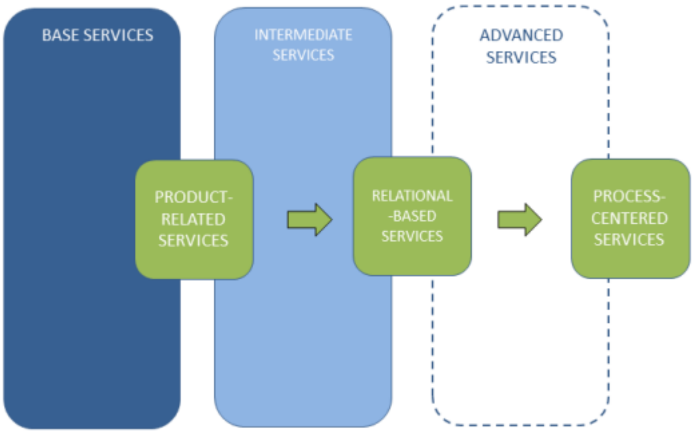

Figure 6: Servitization levels and their core elements, according to (van Schaik, 2016)

1.2 Practical problem

This project will focus on the concept of servitization at Royal IHC. While the Beaver vessel are a successful product, management has indicated a lack of returning customers regarding spare parts during the lifetime of the vessel. This introduces the opportunity to implement servitization elements to the Beaver product. Servitization could allow the customer to focus on their main business, while Royal IHC will take care of any maintenance issues. It would create a closer relation between Royal IHC and the customer and provide Royal IHC with a higher retention rate among customers.

This thesis project has been initiated to create a service design that will increase sales from customers. One of the initial requirements, given by company supervisors, is that there should be a tiered system of three choices in the new design. This tiered system gives the customer the opportunity to choose the level of cooperation with Royal IHC. It also gives design freedom, as it is easier to design an extended service program that fits to all customers if different tiers can be used. By the same logic, it also poses a possible limitation, due to the limited resources currently available. This thesis will try to circumvent this by opting to improve the service by focusing on existing practices.

The extension of service can be presented to the customer when purchasing a Beaver. Currently there is a basic package that functions as a one size fits all, however there are opportunities to modify this service. For example the single spare part package can be presented to the customer as a tiered level of cooperation. Where a "bronze" package will give the customer the needed spare parts for a year of operation under normal circumstances. The "gold" package however, could include close continued cooperation between Royal IHC and the client. With premium access to worldwide spare part locations and service employees. Planned maintenance or operational training are also services that IHC already has in place but are not directly linked to spare part packages or Beavers at the moment. These can be additions to the service provided that add value to customers and therefore to Royal IHC. The main factors that contribute to this opportunity are improved communication, closer cooperation with clients, using internal strengths like experience and expertise, and the recent company restructuring. All these aspects will add to the opportunity that this thesis tries to capture.

1.3 Relevance to Management of Technology

This thesis project has many aspects that can be traced back to the theory from the Management of Technology (MoT) masters program. Since the project involves a change in company processes and service structure, many different stakeholders will have to be managed. Theory and background information about business process management and supply chain management will also play a role in the service environment.

The thesis will also connect these managerial themes in a high-tech environment. Royal IHC vessels contain state of the art technology and the company remains highly innovative in many industries, dredging being one of them. Applying the concepts from the masters program in such an environment creates a unique case, which is very fitting for a thesis. It shows that MoT graduates can connect the theoretical and technical side with a service strategy in a complex system that involves many stakeholders, often with different intentions.

1.4 Keywords & definitions

There are several key concepts in this thesis that will be defined in this section, in order to avoid confusion on their meaning throughout the project.

Service
The action of helping or doing work for someone. This is generally what a service can be defined as. Within the context of this project, service can specifically be seen as the grouping of the following elements: parts delivery, parts installation, technical, maintenance, and operational training, and immediate emergency solutions.

Servitization
The meaning of servitization in the scientific field has already been discussed in section 1.1. The application of the term within this project will be more practical as it pertains to creating one integral solution for the customer. Using the latest data gathering and analysing technologies to completely understand the maintenance challenges and be able to offer a reliable and competitive

service.

Spare part
Every individual part or assembly on a vessel that is able to be delivered after the initial purchase, is considered a spare part to the vessel. In this project, a more detailed categorization will be explored in order to more accurately place spare parts in logical categories.

Service design
During this project, the term service design will be used to indicate the resulting design. This design is an improvement over the existing design, which means that elements of the current service may transfer to the service design that this project will recommend. Included in the service design are both the service elements for customers and the changes in internal processes for Royal IHC.

1.5 Thesis outline

The structure of this thesis will be as follows; In chapter 2, the methodology, the goals of the project will be explained, as well as the limitations. This second chapter will also show the design process that will be used to create the service, and the sub-research questions that help create a base of knowledge in order to make logical decisions.

After the methodology, chapter 3 will show the current state of literature on the subject of servitization. Not only the servitization elements will be investigated, maintenance and service contracts are also analysed as they might become an important part of the eventual design.

In chapter 4, the current processes of Royal IHC are analysed. Every part of the current service will be investigated to find opportunities for the future. This will also be compared to current literature in order to check if the best practices are already in place. The last part of this chapter will show improvements to the current processes that offer a benefit to Royal IHC Services as a whole, but do not directly impact the design of the service in this project.

Chapter 5 will list the requirements that the proposed service design has to adhere to. The requirements are split in two categories, requirements that need to be in the final design, and requirements that would be nice to have in the final design. The requirements will follow from either technical, customer, or environmental factors.

In chapter 6, the actual service design will be shown. First the philosophy behind the service will be explained. After which the elements of the new service will be shown and explained. There will also be a deeper look into the role of stakeholders within the new service design and how it changes from the current service. Lastly, the design will be verified and validated.

In chapter 7, an evaluation study will be done. A new part of the service design will be tested for feasibility using a Royal IHC project in Jordan.

Chapter 8 has a general overview of the main obstacles that accompany the implementation of the service design, however it also contains an initial plan for implementation.

The conclusion can be found in chapter 9, which also has an academic and managerial contribution. Additionally it has some recommendations that show good opportunities for future research. Finally, the last chapter is an academic reflection on this thesis from a personal point of view.

2 Thesis methodology

This chapter will explore the methodology of this thesis project. The goal of this project is to create a service design that increases customer retention. In order to reach that design goal, both research and design components are used. The objectives will be discussed in the first part of this chapter.

In the second part of this chapter, from section 2.4 to section 2.5, the specific methods that are used for the analysis and design are discussed.

The last part of this chapter will put forwards the initial literature search in the field of servitization. Attention will also be given to the project scoping. Finally, the limitation around this project will be examined.

2.1 Project methodology

The design structure in figure 7 is a take on the four steps of the Service Design Thinking (SDT) Model, first published by Stickdorn and Schneider in 2010 (Tschimmel, 2012). This model emphasises that design is not a linear process, it is iterative, indicated by the feedback loop. The four steps, exploration, creation, reflection and implementation have been slightly altered to fit this project.

Because there are many stakeholder involved not only within Royal IHC but also outside of the organisation, like customers, (Li et al., 2020) advises to include a stakeholder analysis. This project will take that advise and include it in the first part of the analysis, due to the fact that having a clear view of all participants and their ambitions or requirements will always be useful.

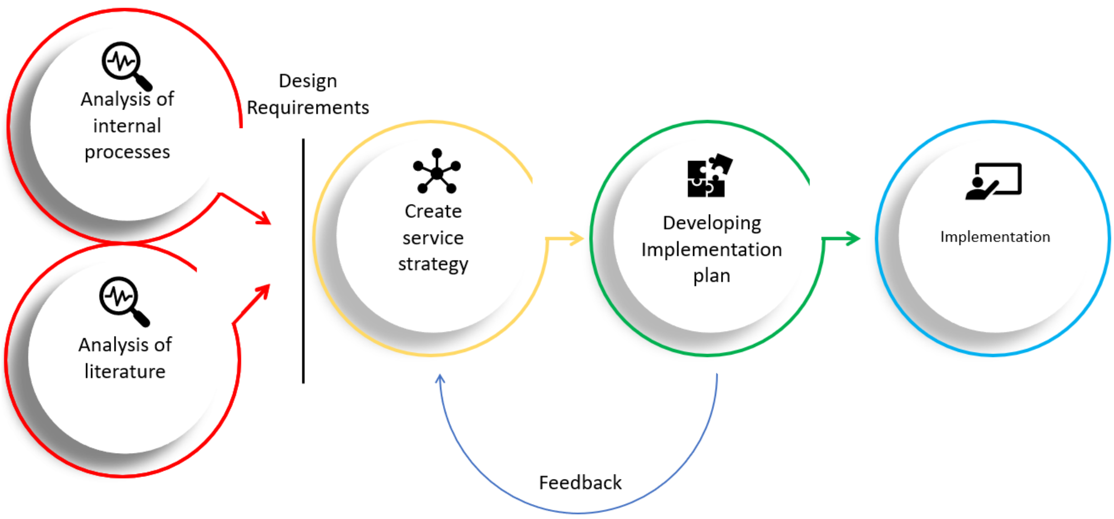

Figure 7: Design process, inspired by (Tschimmel, 2012) and (Li et al., 2020)

In order to gain relevant insights into processes at Royal IHC, communication with employees of different departments that interact with the service is required. Those insights should reflect the current processes and the rationale behind them. The service design and eventual recommendations will follow from there. The improved service design will be communicated to the same people to receive feedback on the perceived effectiveness and feasibility. If the feedback shows vulnerabilities or opportunities these can be handled in an iterative process to eventually get a final design.

Design methodologies usually have an iterative aspect, similarly in the maritime industry. The reason for an iterative process is that there are reflections upon each version and all relevant stakeholder might add important feedback for a next iteration. It follows that such a process can take quite some time, since there will always be room for improvement by doing another iteration. This project does not have unlimited resources. In fact, both time and expert interaction is not unlimited. This makes it hard to do iterative cycles.

It is for this reason that the methodology has been altered. The many iterations have been replaced by a thorough analysis of literature and processes, followed by a fitting service strategy based on relevant requirements. This service strategy has then been shown to relevant stakeholders in order to gain additional insights that can be implemented. By interacting with these experts both in the analysis phase, as well as after the creation phase, enough feedback has been gathered to present a feasible service design.

2.2 Research objective

As mentioned before, this project will have a research and a design component. The research component is discussed first, since it will also happen before the design component in the project. In figure 7, there are two red circles, indicating the research component of this project. The research activities are divided in an analysis of literature and and analysis of internal processes. The end result is an overview of available knowledge in the academic field, plus an overview of available resources and processes within the project company.

The first part that will be researched is the literature. The reason is that it will likely indicate important processes and elements that will be important to know about before analysing the internal processes. It is much easier to analyse internal processes once one knows what to look for regarding best practices. Figure 8 indicates the main research goals that the literature search sets out to explore.

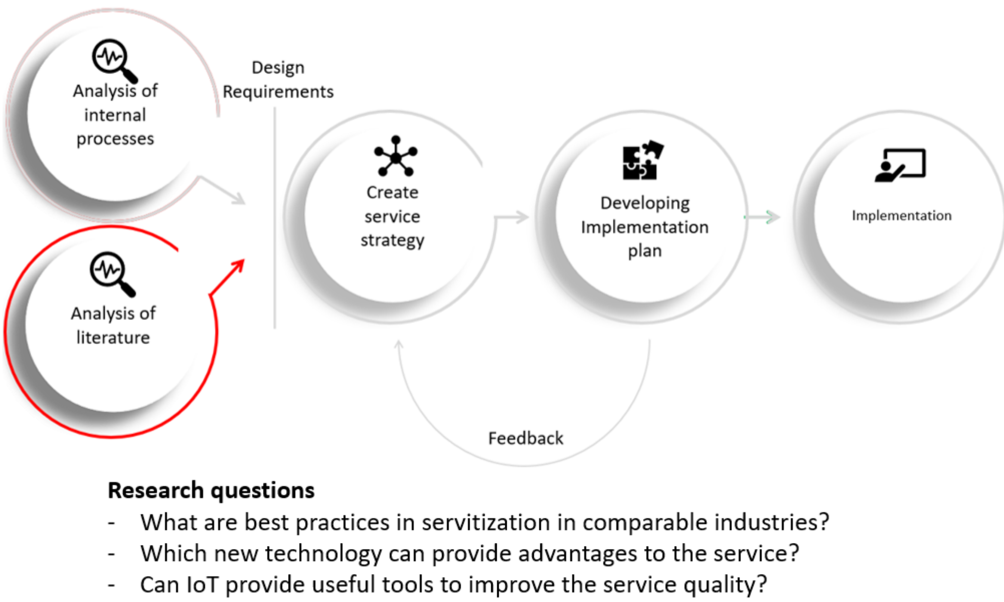

Figure 8: Overview of the research questions regarding the existing literature

The second part of research is done on the internal processes of Royal IHC. Using the knowledge on state of the art servitization that has been explored in the analysis of the literature, the processes of the company can be analysed and related to industry standards. Figure 9 states the research questions that explore the key concepts of the current service. Not only the current capability of the service is determined, the limitations and opportunities are highlighted as well.

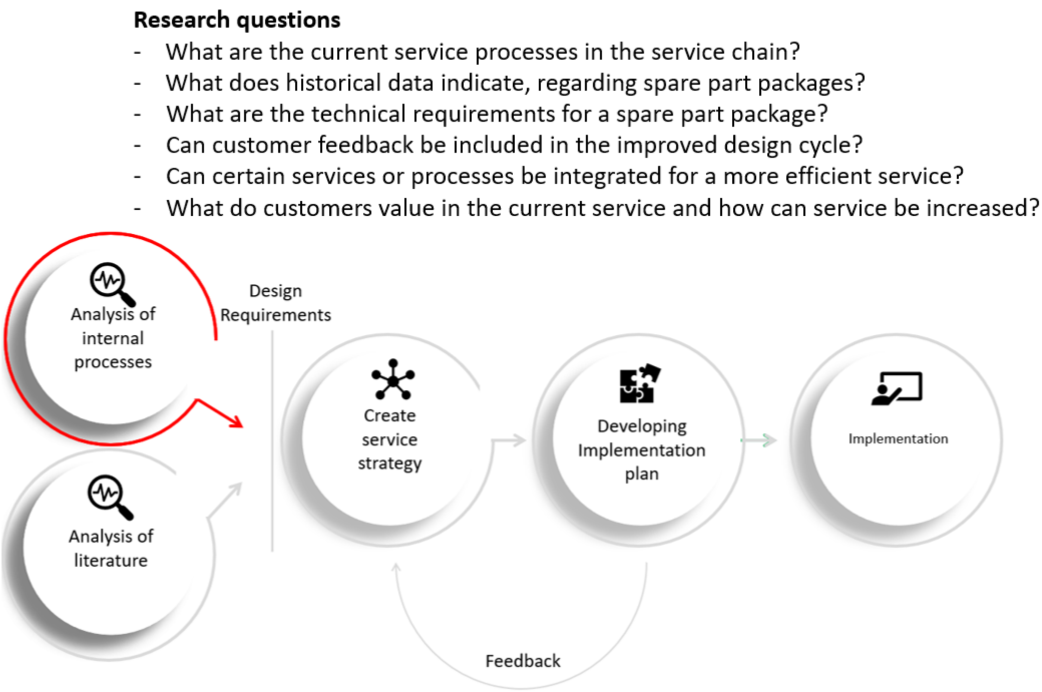

Figure 9: Overview of the research questions regarding the internal processes of Royal IHC

2.3 Design objective

The design component of this project is indicated by the orange color in figure 7. In this stage of the project, the research into the literature and the internal processes has been concluded. This information is used to create the design requirements that are indicated by the black line. It is positioned between the research and the design components of this thesis project.

The design requirements originate from three possible sources:

- Literature
- Current process improvements
- Company requirements

After these requirements have been formulated and confirmed by the company supervisors, the design process can start. The design objective of this thesis is defined as follow;

Design activity: Create a service design that enables Royal IHC to stay the preferred service supplier after the initial sale of a Beaver vessel.

In figure 10 the design questions are listed that will guide the design process.

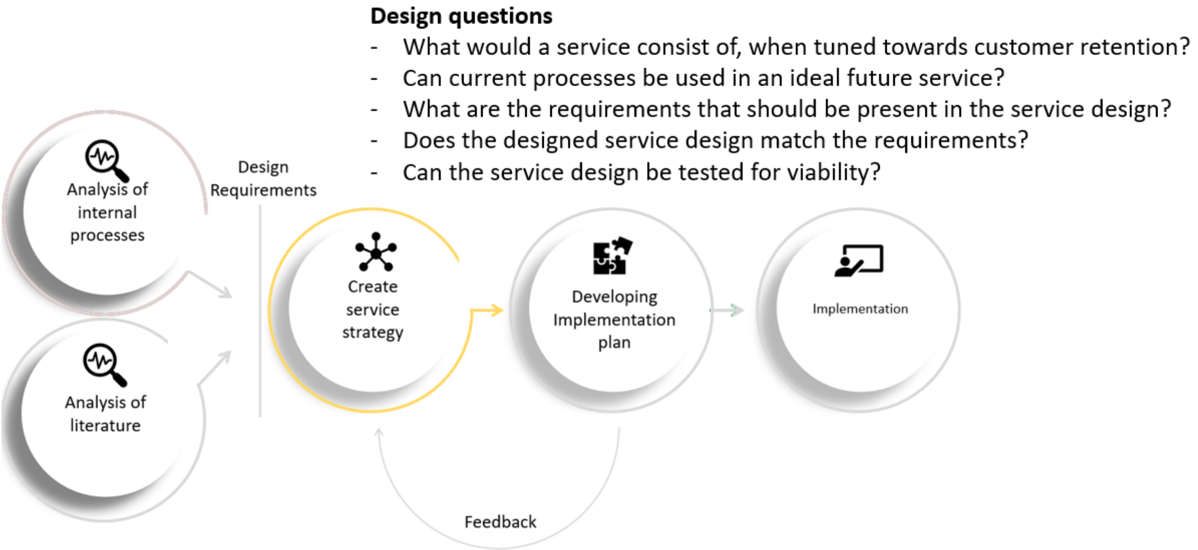

Figure 10: Overview of Design questions that will be explored during this part of the project

The general flow of this design component will be the following. First the requirements are formulated and confirmed. Afterwards, the service design is created. This is done by focusing on customer retention and enhancing current processes. There will be a check if the requirements are met after this design has been completed. There will also be an evaluation of viability in chapter 7.

After the design is verified and evaluated, an implementation plan will be created. In figure 11 the three key objectives of the implementation plan are shown. The service design and its components will be given a relative impact and cost rating. Which can be used by management to evaluate options for implementation. There will be attention for stakeholder involvement, especially if relations between certain stakeholders might change due to the recommended plans.

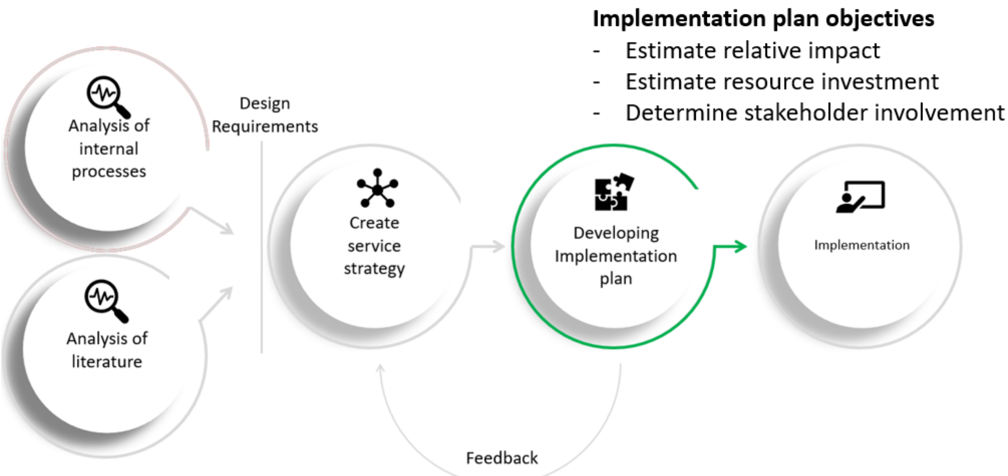

Figure 11: Overview of the implementation plan objectives and their place within the project structure

2.4 Analysis methods

The analysis methods that are being used for this thesis will be a mix between information from literature, analysis of historical data, and meetings with experts within the company. More specifically, the literature can point towards best practices in the field of servitization. The historical data can point towards the efficiency of current practices and technical possibilities within the company. Lastly, and most importantly, experts are used from all fields that this thesis engaged with. These people will be asked about the current practices, with their advantages but also opportunities. There will be room for each expert to explain their own view on the subject of servitization and how their department would ideally see it. After the design has been finalized, a small feedback moment will be planned in order to gain additional insights in the service design and its implementation.

The design objectives will be shared with all experts, after which their own view on the ideal service will be asked. This information will present a view from each stakeholder on an ideal future service. Overlap between different experts might indicate a process that could be easier to implement or that can expect less resistance. Different goals of departments should also be taken into account. Whereas something like predictive maintenance could be hugely beneficial to many stakeholders, it might provide resistance from other stakeholders. These stakeholder related issues will be discussed later in this thesis.

As for the research questions, the stakeholders involved are as such. For the first research question, the question will be answered for each part of the service and stakeholders that are knowledgeable to that part are consulted. The historical data mentioned in sub-research question 2 is general sales data, part information, and historical sales numbers. Technical requirements will follow mostly from engineering data, maintenance needs or technical processes within Royal IHC. Customer feedback is an important aspect that will help improve the service, therefore this data will be included and provide and answer to sub-research question 4 and 6. Sub-research question 5 will have all stakeholders involved. This sub-research question will get answered while the analysis is being done. It might very well be, that after the initial analysis of processes, new information indicates further optimization. In that case, a new round of research can be done in order to answer sub-research question 5.

2.5 Design methods

During the design component of this project, the methods will differ due to a difference in activities compared to the analysis in the research part. First are the requirements that are constructed and discussed in chapter 5.

The requirements will originate from one or more of the following three sources; literature, results from the process analysis, or company requirements. The requirements that follow from the literature will have their source indicated with a discussion as to the relevance of the requirement to this project. Results from internal processes are taken from chapter 4, where the processes were analysed. There is some overlap with literature, since the internal processes can be compared to industry standards and best practices. Once again, their relevance is discussed with statements from experts that confirmed those requirements. Lastly are the company requirements. These requirements are hard requirements that either initiated the project, or came from management during the project. These requirements are discussed on their merit and relevance, however due to them being hard required from company management, they will be included for the final design. The complete set of requirements will be confirmed by the company supervisor as well as a Beaver vessel specialist.

The design process itself is twofold, since there are two aspects that need to be created. The first aspect is the customer service division. Using the required tiered service system. This means that the available service elements have to be assigned to different tiers in a way that makes sense with the goal of increasing customer retention.

The second aspect is the underlying processes of the service design in the company. There will be distinct changes between the current situation and the proposed service situation. These changes will be indicated and explained. The involvement of stakeholders is also an element that will be discussed, especially if it changes significantly between the proposed and the current situation.

There is an iterative process at work in this design phase of the project. The aspects that have been mentioned above, they are highly depended of each other. Changing the services offered, will obviously impact the underlying processes that support those services. This is why there will be meetings with experts in the service department during the service design. Constant feedback will be provided on both the way the service elements are divided in the service tiers, as well as the feasibility of the underlying processes.

Lastly, the eventual service design is going to be verified and evaluated. The verification process will compare the service design to the requirements that have been constructed in chapter 5. The evaluation will based on a comparable service already being carried out by Royal IHC. The similarities, differences and limitations of the service design compared to the case will be discussed in chapter 7.

2.6 Literature search

The initial literature search consists of finding state of the art practices in the main aspects of service. Maintenance, operational profiles, and fleet management are some of the important fields that this thesis will interact with in some capacity.

Table 2: Key words and their synonyms

Theme	Synonyms
Servitization	Service-driven manufacturing, Service infusion, Service transition, Product-service system
Maintenance	Upkeep, Support, Preservation
Digitized product-service	IoT, IIoT, Smart Manufacturing, Digitization
Operational Profiles	

Table 2 describes the search terms and their synonyms used for the literature analysis. Combinations with the "maintenance" and "Servitization" search terms provided insights in the applicability and ease of implementation of the service design. In the field of maintenance, important works like Dekker et al. (1997) have been added, due to good definitions of types of maintenance still relevant today. The search term "Operational Profiles" comes from works like Blanchard & Fabrycky (2011), but have more and more use with new monitoring and data analytics nowadays.

In table 3 the inclusion and exclusion criteria are shown for the research topic. Loyalty schemes do not fall in the scope of this process, since it is mainly used in different types of business. Therefore papers that focus on this part of servitization will be excluded for this thesis. Regarding the time period, there is a split between state of the art and established maintenance practices. Some concepts, like maintenance, from longer ago are still relevant, while the operation

Table 3: Inclusion and exclusion criterion

Criterion	Inclusion Criteria	Exclusion Criteria
Technology	Servitization, Maintenance, Operation profiles	Loyalty schemes
Period	Articles after 2010	Articles before 2010. No restriction on maintenance papers
Study type	Journals, Books, Peer reviewed scientific journals	Opinion pieces, Patents
Publication language	English	Other languages
Research field	Business, Maintenance, Social Science	Engineering, Mathematics
Accesability	Research available through TU Delft tools	No TU Delft acess

profile and servitization should be relatively recent, as big steps have been taken in recent times. Patents are excluded from this review because the aim of this literature search is to gain a better understanding of the current views and progress in the academic field. Patents often revolve around complicated mathematical or theoretical details that do not help create the overview that this search wants to achieve. Lastly, only literature available through the online resources of the TU Delft is considered.

2.7 Scoping

In the book, Engineering Design, Planning, and Management, Hugh Jack defined the design objective as follows; a set of basic requirements and hopeful outcomes, that are subject to realistic constraints (H. Jack, 2013). The danger lies in that what is not clearly defined, therefore design objectives and functional requirements are key. Design constraints are defined as the limit to where the project is considered acceptable. In order to avoid unclear objectives and the following unsatisfactory results, scoping of the project is critical. Included in the project will be the following:

- Recommendations on extension of current service, possibly tiered in a bronze, silver and gold level.
- Classifying the spare parts in corresponding categories in order to create a better understanding towards improvement.
- Identifying value for customers and the opportunity for Royal IHC to capture it.
- Exploring options for service contracts that include longer commitment between Royal IHC and its customers.
- Explore a continuous feed-back loop that would allow for constant improvement of services, based on feedback from customers.
- Realize an initial implementation plan for the given recommendations.
- Initial service design will be designed for new Beaver vessels.
- The design will follow a 'brownfield' approach.

Not included in this project will be the following:

- Complete detailed technical analysis of current and future spare part packages.
- Service package for existing Beaver vessels

The recommendations that result from this project should be clear enough for implementation. However, it should be noted that this project is not solely about the technical change of the contents of the current packages. It goes further towards expanding service level towards customers and creating opportunities that are currently unused.
The 'brownfield' approach essentially means that this project will improve the existing design. Contrary is the 'greenfield' approach, which would just focus on the ideal solution without regard for the current situation, since that does not impact the ideal solution in most cases (Axehill et al., 2021). Due to the company circumstances, the brownfield approach makes the most sense. Resources for investment are scarce and many services are already in place. While a greenfield approach might position a company better due to new and efficient processes, brownfield allows for existing processes to be used as the stepping stone towards a better service.
This project will focus on creating a design that is applicable to new Beaver vessels. This has the disadvantage of excluding a sizable installed base, which leaves a lot of potential revenue on the table. However, the main difficulty is the unknowns in the installed base, amplified by the time restriction on the project. The installed base has vessels from 30 years ago, most of whom have different parts or obsolete technology. It would take an unrealistic amount of time to create the maintenance and part details that includes all these different vessels that also are in an unknown state to Royal IHC. The service design itself would not change a whole lot, however due to these intensive extra steps, the implementation of the initiative would become less attractive. If this initiative satisfies the goals on new vessels, it would definitely be worth it review options of including the installed base. However, there are too many unknowns combined with the time restriction to be able to properly include them at the moment.

2.8 Limitations

This thesis project will face two categories of limitations that will impact the research and implementation plan. General limitations are factors that any project is subjected to, like time and access. Whereas this project also has company specific limitations, like information reliability and verification. Figure 4 has the main limitations listed with their cause and countermeasures.

Time is a huge general limitation, due to the time window in which this thesis project must be completed. The implications for this project are that not every aspect of this project can be completely analysed and sometimes decisions have to be made in order to continue. Having a resilient planning and strong scoping will help keep the project within this time constraint.

The limited access to data from outside systems and companies will restrict this project in comparing designs. Since a service design relies heavily on internal processes, it can prove to be difficult to analyse them in other companies or sectors. This results in a greater dependency on internal resources from Royal IHC and published literature.

This thesis has a design goal as the main deliverable. This design is limited by the aspects that are specific to Royal IHC, not necessarily sector wide. This results in a service design that might have little generalizability, due to being heavily constrained by factors not present elsewhere. The design philosophy and requirements will therefore be explained in order to gain insights in these specific conditions for servitization. This should create an image under which circumstances this project will work in other environments.

The company specific limitations are a dependency on internal knowledge. During this thesis project, many experts from within Royal IHC will explain internal processes or experiences within Royal IHC and the dredging industry. This is justified due to the fact that this knowledge is needed for the project and can not be obtained in another way (Bogner & Menz, 2009). While this offered an opportunity to gain expert knowledge, it also gives problems regarding internal

Table 4: Limitations on the project, both of general nature and company specific

Concern (general)	Cause	Countermeasure
Time	Predetermined timeframe in which the project needs to be finished	Create a resilient planning with wiggle room, combine this with strong scoping.
Limited access to data	While some servitization models from other companies can be viewed, the specific processes and infrastructure remains invisible for outsiders	Greater dependency on in-house resources.
Limited generalizability	The service model will be formed to the requirements and whishes of Royal IHC. This will depend on certain conditions not present at competitors	The design philosophy will be explained, also a review will be done on each requirement. This should provide insights into the conditions for servitization

Concern (IHC specific)	Cause	Countermeasure
Source of information	In a large company, specific information could be hard to find	Using the network of my company supervisor to efficiently connect with the right people
Validity of information	People might be locked-in to older practices without being aware of it	Confirm statements with other people knowledgable on the subject, or with academic literature
Testing for validity	Testing a new model without an existing real world counterpart creates a problem regarding validity	Using a recent case within the company that uses the same competences as the proposed model

validity. This has been limited by using secondary sources of information to check statements made by experts, like websites, videos, articles and books (E. P. Jack & Raturi, 2006).

2.9 Sub-conclusion

In figure 12 the methodology that has been introduced in this chapter is displayed. This figure has numbers in the subjects, indicating which chapter is used to do each project activity. Additionally, each chapter in this thesis will have the following figure included, in order to have an visual aid for which part of the thesis will follow.

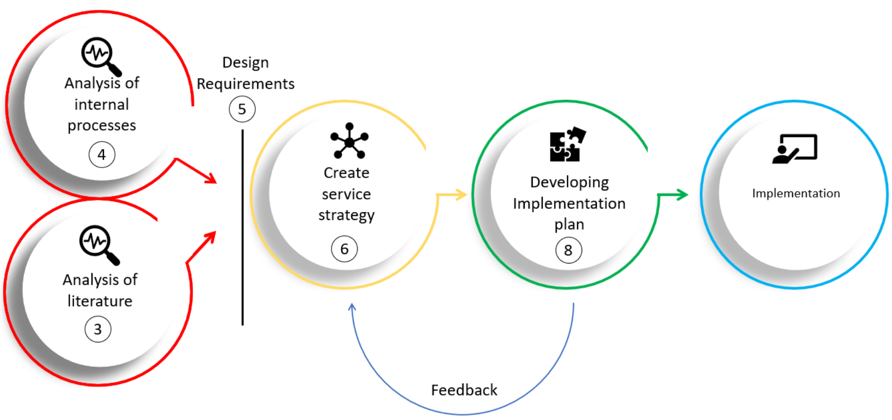

Figure 12: Design process, with chapter indications included, inspired by (Tschimmel, 2012) and (Li et al., 2020)

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3 Servitization state of the art

As indicated by figure 13, this chapter will focus on the state of the art literature that will be encountered during this design thesis. Not only subjects that directly influence the decisions made, but also subjects that are adjacent will be considered. The conclusions of this research, coupled with research results from chapter 4, will lead to the design requirements.

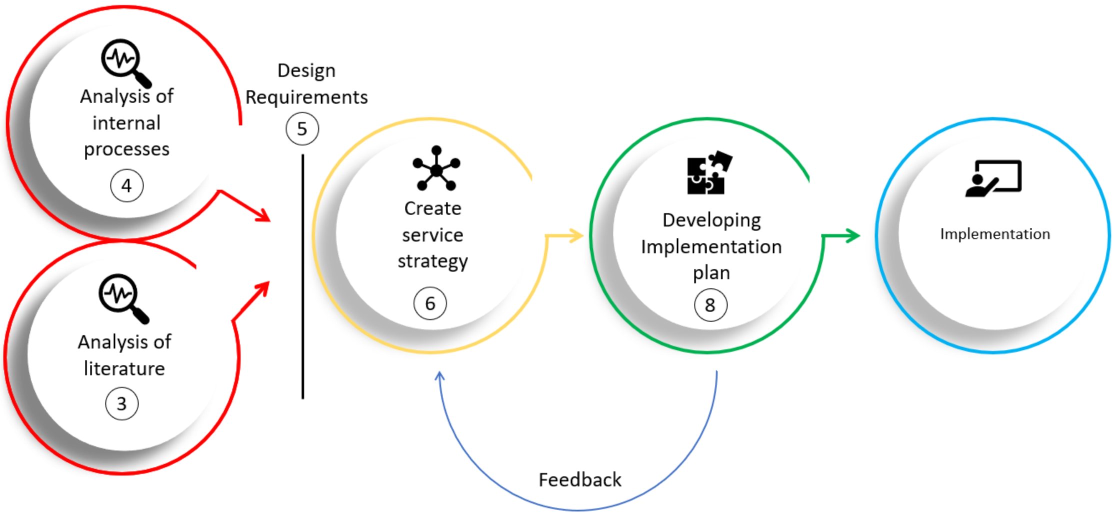

Figure 13: Design process, with chapter indications included, inspired by (Tschimmel, 2012) and (Li et al., 2020)

To preface the industry setting that this thesis is taking place in, the MaSeLMa project offers an overview with characteristics in the dredging industry. The MaSeLMa project has the goal to ultimately reduce the total cost of ownership for owners of vessels, and provide service providers with new opportunities. Under guidance of Dinalog, a Dutch collaboration between universities and industry, weekly meetings took place with many maritime companies and partners in order to classify the most important characteristics of maritime maintenance and service logistic management (*MaSeLMa - TKI Dinalog*, 2016). The results are a combination of literature findings, lessons learnt, and brainstorm & feedback meetings with industry practitioners. Some of the findings that are relevant to the dredging ecosystem are the following; (Eruguz et al., 2017).

- Vessels are multi-echelon structures
- Vessels are moving assets
- Assets have long life-cycles
- The maritime sector should be viewed as a multi-actor setting
- Failure-related data is not a very reliable source of data

The multi-echelon structures relate to the fact that most vessels consist of many different technical systems that are coupled or operate parallel to each other, contributing to the overall performance of the asset. The main takeaway here is that vessels have very complex technical systems that can have separate functions contributing to the overall performance. The system that provides the propulsion is completely different than the system that provides the dredging operation, however both are needed for optimal asset usage.

Vessels being able to move across large bodies of water creates geographical difficulties, mainly for maintenance and spare part management. Combining this with the fact that vessels have a long life-cycle that can surpass 30 years in some cases, means that there is a need for a robust after sales strategy in place.

The maritime sector as a whole should be seen as a multi-actor setting. This is no different when looking at the dredging part within that sector. Royal IHC mainly functions as a provider of new vessels for customers, where services can be provided afterwards. Maintenance, training or operational advice and support are all elements of interaction that Royal IHC has with the operators within the dredging industry. Add subcontractors, suppliers and dredging job providers in there and there is a complex web of actors that create this industry.

Servitization is the term that is used to indicate that manufacturers do not only focus on selling their product, but creating an additional service around the product to create additional value for the customer (Raddats et al., 2019). The customer does not pay for the product, but the output generated by that product. This is currently seen in the aviation propulsion sector, where the availability of engines is sold instead of the actual engine. Whereas this example in the aviation industry has fully embraced the servitization of engine usage, the mentality of putting the focus on customer satisfaction instead of selling products serves the same need but to a lesser extend. Since the customer retention is one of the main goals of this thesis, shifting the focus towards customer satisfaction can play a key role in improving the service.

3.1 Maintenance

Figure 14 shows the expected demand intensity for capital goods during their lifetime (Arts et al., 2019). As expected, in the beginning of their lifetime, demand for spare parts is relatively low, whereas during most of their lifetime, sales stay quite constant. This trend is also seen in practice with Royal IHC Beavers. Due to the degradation of key parts, sales of spare parts will stay quite constant for most of the vessels lifetime. This figure is used to show the expected demand over the life cycle of a general capital good. While Beavers generally would behave like the graph suggests, there are quite some aspects that can influence maintenance rates, like operator skill level, intensity of usage and the soil conditions. These aspects can influence the rate of parts needed and the eventual lifetime of the vessel. Which in turn would mean that figure 14 is higher or lower in the volume phase, as well as the fact that the life can be extended beyond the values seen in the graph. This underlines that comparisons between generalized values and individual samples are bound to have differences. However, the overall shape and phases of the figure are also seen in the Beaver models.

There are many types of maintenance and ways of implementing maintenance plans. In order to get an understanding of current practices of maintenance it is important to understand their differences. Listed below are the most frequent maintenance types to the dredging industry with explanation.

- Corrective/Reactive (run-to-failure).
- Preventive maintenance.
- Opportunistic maintenance.
- Predictive maintenance.

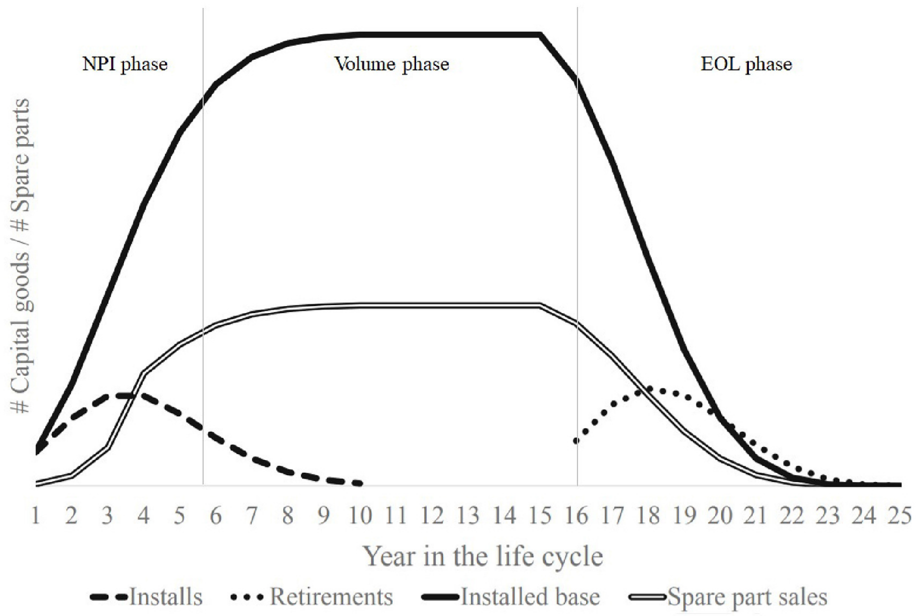

Figure 14: Expected demand intensity for spare parts for capital products from the installed base (Arts et al., 2019).

In the dredging industry, all these types of maintenance appear. However, not every form of maintenance is ideal in this industry (Mouschoutzi & Ponis, 2022). Corrective maintenance can lead to disruption of service, which can be prolonged for quite a while if the part needed for the maintenance is not available or located somewhere else.

Preventive maintenance is planned beforehand, based on either technical calculations or observed metrics, like performance data. At Royal IHC, planned maintenance is already carried out for certain vessels or projects (Maintenance manager, personal communication). However, for Beavers this service is currently not available.

Opportunistic maintenance is a combination of preventive and corrective maintenance. Corrective maintenance is something that will always be needed in case of a failure. However, as Dekker et al. (1997) explained, it can also be seen as an opportunity to perform preventive maintenance on other parts now that the machine has downtime anyways (Dekker et al., 1997). Preventive maintenance has a highly planned character, whereas corrective maintenance is often unexpected. This might make the combination less ideal because you lose the ability to accurately plan your maintenance activities. However it can still be useful in certain situation where either the preventive maintenance of other parts can be advanced on occurrence of a failure, or where the corrective maintenance can be delayed until the next planned preventive maintenance moment(Dekker et al., 1997).

Predictive maintenance is a concept that has gained ground with recent developments regarding the acquiring, storing and analysis of big data (Killeen et al., 2019). It has the ability to increase up-time of equipment due to more information being available. This is certainly a technology worth investigating, however it can be a costly investment due to the fact that not only the data needs to be gathered. It also needs to be stored, analysed and turned into a workable maintenance plan. This would likely take quite some time to effectively implement.

3.2 Planned maintenance systems

Collaborative replenishment and the role of an intermediary in the supply chain. Hezarkhani et al. (2018) argues that while an intermediary would add costs to each individual product, a grouped delivery from multiple manufacturers to a client could benefit from consolidation and shipping advantages. Also having the added benefit that the customer only interacts with the intermediary instead of a large number of different suppliers (Hezarkhani et al., 2018).

3.3 State of the art failure related data

Event data is equally important as condition monitoring data and should therefore not be underestimated in condition based maintenance (Jardine et al., 2006). The reason being that it is important to understand the reason for certain patterns when analysing monitored data. If companies are able to link certain behaviour to specific events, this can improve the understanding of the monitored data in the future.

Operational environment is an important factor when considering effective maintenance, especially in the maritime sector where environmental influences have a large impact on behaviour and performance of assets (Dekker et al., 2013). As mentioned before, dredging vessels operate in harsh environmental conditions. Like other maritime vessels, the salinity of the sea will affect all seagoing dredging vessels. However, dredging vessels also have the additional interaction with the soil that is being dredged. The type of soil can range in toughness from sand to rocks, but may also have additional elements like mud, where muddy soil can stick to equipment leading to accelerated wear or a dip in maintenance.

Vliegen et al. (2010) warns that investing towards a high level of asset monitoring does not guarantee a higher asset availability. The biggest reason is that maintenance resources like spare parts or maintenance engineers have to be managed to the same degree (Vliegen et al., 2010). Having an accurate view of the condition of a vessel and its maintenance needs, does not directly translate to an operational vessel with a high degree of availability. If maintenance needs are found from asset monitoring, the maintenance itself has to be done in a timely manner, otherwise the added benefit of the monitoring systems is little.

3.4 Part criticality

Research has been done on classifying criticality by Molenaers et al. (2012) in 2012. Their goal was to determine the level of criticality based on criteria, shown in figure 5. If the level of criticality is known, inventory management can be adjusted accordingly (Molenaers et al., 2012).) A specific part would be assigned the vital, essential or desirable tag, based on their performance on each criteria. A Gearbox that has a delivery time exceeding one month would get the vital tag for that specific criteria. Whereas the probability of failure would get a desirable tag due to its general low frequency of failure. By assigning weights to each criteria, a single number that indicates criticality can be calculated for each part. This number would reflect the relative criticality that is assigned to that part, which can be used to plan inventory management.

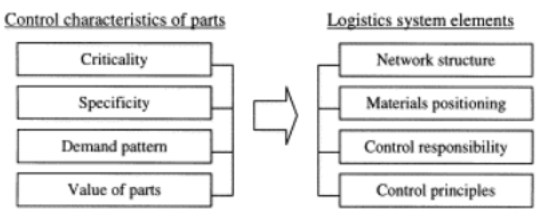

Figure 15: Control characteristics relevant to spare part management (Huiskonen, 2001)

Table 5: Criticality criteria measurements (Molenaers et al., 2012)

Criticality criteria	*Categories*		
	Vital	*Essential*	*Desirable*
Equipment criticality class	Criticality classes A, B	Criticality classes C, D	Criticality classes E, F
Probability of item failure	≥1/year	≥1/5 year and <1/year	<1/5 year
Replenishment time	>1 month	>2 days and≤1 month	≤2 days
Number of potential suppliers	Only 1 supplier	>1 and ≤3 suppliers	>3 suppliers
Availability of technical specifications	Not available	General specifications available	Detailed specifications available

In the 2001 paper by Huiskonen (2001), a further explanation is given towards dividing parts beyond their criticality. In figure 15 these characteristics are shown. As previous literature also indicated, criticality is in practice the first feature that inventory managers and maintenance managers are interested in. However, the other characteristics in the figure can guide towards dividing spare parts regardless of their criticality.

Specificity can be explained by separating all spare parts in two categories, widely used standard parts or tailor made for specific use only. The first category usually has a high standard of availability, since suppliers have relatively high selling volumes and can design their supply chain in a way to take advantage of economies of scale. The opposite is often true for parts that are tailor made for specific use cases. Low sales numbers means that suppliers are unwilling to stock the special parts and take on the responsibility of keeping availability (Huiskonen, 2001).

3.5 Fleet management & Service contracts

In this project, a closer look will be given to the possibility of increasing cooperation with customers in the maintenance of their vessels. This would increase service level perceived by customers and could provide more reliable revenue streams for Royal IHC. During this project, Systems engineering and analysis by Blanchard and Fabrycky will be used (Blanchard & Fabrycky, 2011). They have extensively documented service and maintenance on complex systems, which will be useful in the context of this project. This literature will be used to check general statements regarding maintenance from Royal IHC employees.

A performance service contract is useful in situations where performance is easily calculated or determined (Horenbeek & Jordan, 2012). In dredging, production, up-time and vessel availability are metrics that accurately reflect performance. Therefore, this could be a direction worth exploring of future service.

3.6 Operational profiles

A case study on city busses tried to gain the same insights into linking usage data and maintenance. Sensors were placed on a fleet of city busses and researchers were able to spot common issues in their data (Killeen et al., 2019). They used software called COSMO, designed to autonomously accumulate a lifetime database based on behaviour within expected variability under normal circumstances. The system can spot differences in behaviour without the need for experts to point them out beforehand (Rögnvaldsson et al., 2018). Since Beavers are very much a standard product and customization is kept to a minimum, resulting data could be comparable enough for implementation of such sensors. There are many differences like geographical deployment, operator skill level and much more, which can make the results unreliable. However, if such software is implemented correctly it would allow for effective preventive maintenance. This decreases downtime of the vessel and would positively impact the experience of the customer.

3.7 Digital servitization

Increased digital communication capabilities to create value co-creation, with the help of wireless communication devices. Sharing consolidated information provides closer customer relations, which can be an important metric for servitization focused manufacturers (Lenka et al., 2017). This technology is offered via E-WON, digital communication from the vessel to Royal IHC. However, not all aspects that Lenka et al. (2017) mentions are fully utilized. The mechanisms mentioned in 16 are underused at the moment at Royal IHC Beavers. The information flows from the vessel to E-WON, which can be accessed by both the customer and Royal IHC. However, the ability to create additional value is underused. The information is operational in nature and limited to basic dashboard metrics. Both the ability of the customer to provide additional information and the ability of Royal IHC to act in response to the received data are underused.

Martín-Pena et al. (2020) Supports the digitization of communication by providing a framework in which servitization and company performance are mediated by digitization. Where digitization can lead to improved servitization practices and thereby improving company performance (Martín-Pena et al., 2020).

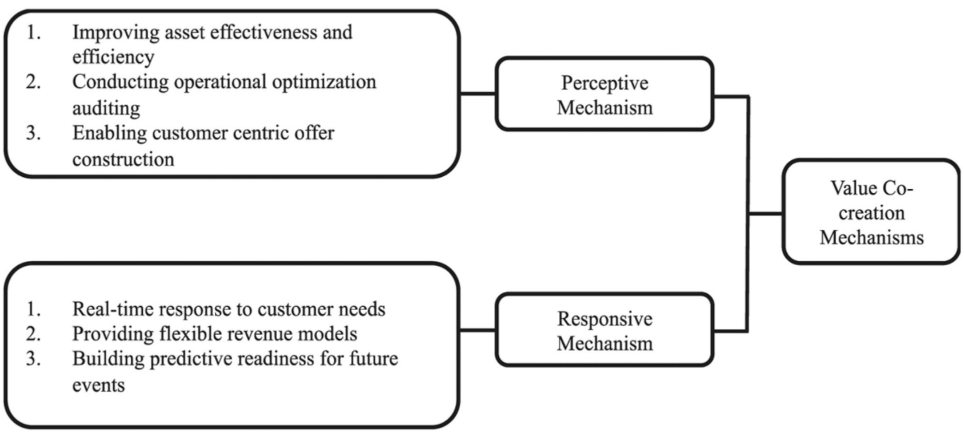

Figure 16: Value co-creation mechanisms through digital capabilities (Lenka et al., 2017)

IoT integration in servitization

There are three outcomes that are relevant when examining IoT solution for manufacturers that want to apply servitization practices, according to (Naik et al., 2020). Basic outcomes, internal outcomes and external outcomes. The basis outcomes are about the collection of information about the product and the visibility of usage data. These are the basic outcomes that IoT will support. Internal outcomes pertain to the internal processes of manufacturers, such as their service design and repair or maintenance activities. These internal processes can be hugely helped by having strong IoT support. Lastly, the external outcomes are about the relation with the customer. Helping customers with their business and improving the service achieves a closer customer cooperation which crucial to servitization initiatives (Naik et al., 2020). These three outcomes can be seen as the pillars that need to be in place in order to effectively use IoT in servitization programs.

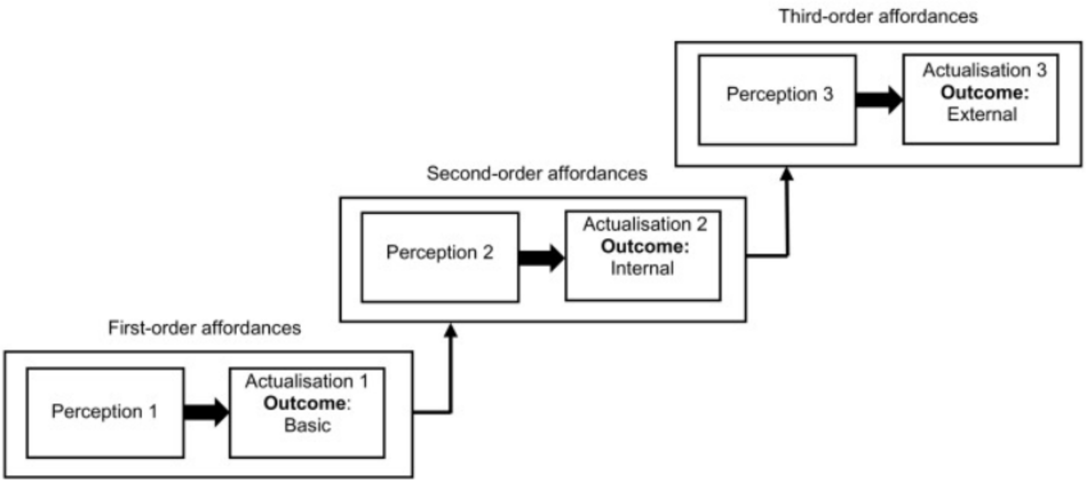

Figure 17: Affordances framework enabled by IoT (Naik et al., 2020)

Figure 17 states that the three outcomes will act in a primary, secondary and tertiary relation. In order to provide the customer with the improved service in the external process, the company must have their internal processes in order. Which insinuates that before that the basic outcomes should be in place. So in order to satisfy customers and increase servitization performance, all these three processes should be in place and at a certain level.

The biggest takeaway from this is that when trying to increase customer satisfaction through servitization, the data collection and visibility of usage should be in place. Secondly, the internal processes should be reflective of the service that is designed. If these processes are in place, the external outcome will provide the customer with a servitization that can actively support their product with relevant processes and information.

In their paper, (Rymaszewska et al., 2017) indicated that there are several IoT solutions that can power servitization in manufacturing. IoT promises more control and better monitoring, due to more accurate and a larger quantity of data. IoT will allow physical devices to use intelligent networks, these devices can be sensors or actuators that communicate with each other or directly across networks to enable effective business decision making (Lee & Lee, 2015). This is achieved by creating more accessible and accurate data on products or processes. This gives managers more relevant information to base their decision on, which in turn creates more effective decision making.

Radio Frequency Identification(RFID), allows the capture or exchange of information with radio waves, a reader, and a tag. This tag can contain any information that is or will become relevant to the process. Implementing this technology offers many advantages in complex supply chains, where information is sometimes lost in paperwork. The tracking and capturing of information of items in the supply chain offers much more transparency and control for your operation. Therefore this technology offers great potential for manufacturers that want to implement IoT in their processes (Malik et al., 2021).

Wireless Sensor Networks(WSN) are networks of autonomous sensors that are distributed in the area of interest. They can communicate with RFID devices and monitor conditions like their movement, location, and temperature. With these properties they are great for keeping track of temperature sensitive equipment or goods. WSN can also be used as a feedback system on status and conditions of processes and machines. Since many conditions can be measured, predictive maintenance can reduce downtime or unsafe environments.

Middleware helps software communicate by creating a software layer between different applications. The result is that every software application communicates with the Middleware in inputs and outputs. The advantage of this is that it creates a much clearer interaction between software programs. If you use multiple different IoT devices, all of whom have different software, it can be a tough task to make them communicate in a clear way. Middleware reduces the programming to inputs and outputs, which means that it is not needed to modify each program in such a way that it can work in your network. Due to the fact that it makes it easier to connect many different applications and devices, Middleware is a great tool to use when implementing IoT (Lee & Lee, 2015).

A combination of these applications makes machines, supply chains or processes smarter. RFID achieves somethings not manageable before, combining the product and information flow in a comprehensive way. Experts working with McKinsey see a future where manufacturing would combine the product and information flow (Löffler & Tschiesner, 2013), a product will be inextricably linked to its information. This allows easier exchange of information and better tracking. Middleware is the invisible layer that is absolutely needed for clean integration, however it is not the component that gathers data.

3.8 Servitization in different sectors

This project specifically handles servitization within a maritime manufacturing setting. However, servitization has opportunities far beyond just the maritime manufacturing environment. By analyzing key takeaways from other sectors, insights useful to this project might be obtained.

Aviation engine manufacturing industry

In the aviation engine industry, Rolls-Royce has been a leading player in providing engines as a service. Aerospace engines are very complex in nature and have a lifetime of over twenty years. Every five years a complete overhaul of the engine is required, leading to downtime and high additional costs. Where the maintenance was previously done by the airline operators in-house technical team, this has been changed to cut costs in the competitive area of long distances transportation. Instead, airlines focus on their area of expertise, actually transporting passengers.

Rolls-Royce used this situation to launch their servitization program. A concept named "Power by the hour" would charge customers for every flight hour that an engine made. It let the airline operators focus on their own core business, while Rolls-Royce would take on all service and maintenance on the engines. Availability and reliability became the priority for both the airlines and Rolls-Royce. Whereas before this initiative, Rolls-Royce would create revenue from product breakdowns. Rolls-Royce has transformed from a manufacturing company to a service provider, thereby standing closer to their customers. This is underlined by the fact that their goals, availability and reliability, are aligned.

Their service has since been continuously improved upon. Introducing services like "engine health monitoring", "logistics management" and "spare part support" (Baines et al., 2013).

Rolls-Royce has shown that aligning the company goals with the goals of the customer can lead to a successful service. It capitalized on letting the customer focus on their core business while Rolls-Royce would focus on their own core capabilities, which lie in the technical and maintenance space.

Truck manufacturers

The trucking business experienced a servitization transition during the financial crisis of 2007. Where in the early 2000's trucking companies like DAF, Scania, and MAN were able to rely on increasing sales number, during the financial crisis sales plummeted, due to the absence of credit from customers. Trucking companies acted on these circumstances by offering trucks with integrated advanced service.

Instead of selling trucks, the trucking companies sold service contracts to their existing customers that would also cover already purchased trucks, the installed base. This resulted in renewed profitability for the trucking companies, however it also presented a shift in how the revenue was generated. Trucks were actually sold below manufacturing costs.

This service model has been improved upon over time, to the point where nowadays the service model is much more than just a truck with maintenance and repair services. It has extensive worldwide support and fleet management services. This resulted in a completely different business environment compared to before 2008 (Baines et al., 2013).

This case indicates that the relatively simple idea of offering a product with a maintenance service can evolve in a sophisticate service model that defines the business.

3.9 Sub-conclusion

There is available literature that is applicable to the practices that Royal IHC has regarding Beaver vessels. Maintenance practices offer a path towards servitization when being able to capture enough information to accurately determine maintenance needs. This servitization aspect would be beneficial to this project, since it amplifies the service that Royal IHC can offer to customers. Not only can it lower the maintenance load for customers, it can also improve overall up-time and readiness of the vessel.

Behind the scenes, there is also room for improvement regarding the maintenance classifications, especially criticality. This is an internal opportunity, which has potential to streamline inventory policy due to increased awareness of spare part usage and criticality.

Research has shown that operational profiles can be used to accurately determine the condition of a vessel. In order to generate these profiles, a couple of challenges still exist. Geographical aspects, operator skill level and the maintenance regime followed by the operator are all factors that will make each vessel unique. However, there should still be possibilities to create a more general operational profile, either by region or for different environmental conditions.

Another opportunity that will be explored in this project is the service based contract, which is already being used in other sectors. Due to the reasonably simple output metrics, it is pretty straightforward to set targets for the contract. Especially since Royal IHC already performs all the maintenance required for vessels when customers ask for it.

Digital servitization literature indicated that a strong digital information support system is important for maintenance integration. Important IoT technology has been introduced that allows huge amounts of information to be collected and stored. Finally, two other sectors that have made the switch from strictly manufacturing to offering servitization. Important lessons have been to align company goals with the customer goals, and to focus on the core competencies.

There seems ample opportunity to implement state of the art maintenance and servitization practices in the current and future processes of Royal IHC Services.

4 Analysis of current processes within the service chain

This chapter will focus on answering the research questions particular to the existing situation at Royal IHC. As indicated by figure 18, this chapter is part of the research component of this project. Most of the information will be gathered by interacting with employees responsible for a certain part of the service chain. However, parallels with adjacent industry practices will also be explored in order to review the effectiveness. This information is then used to construct the design requirements in chapter 5.

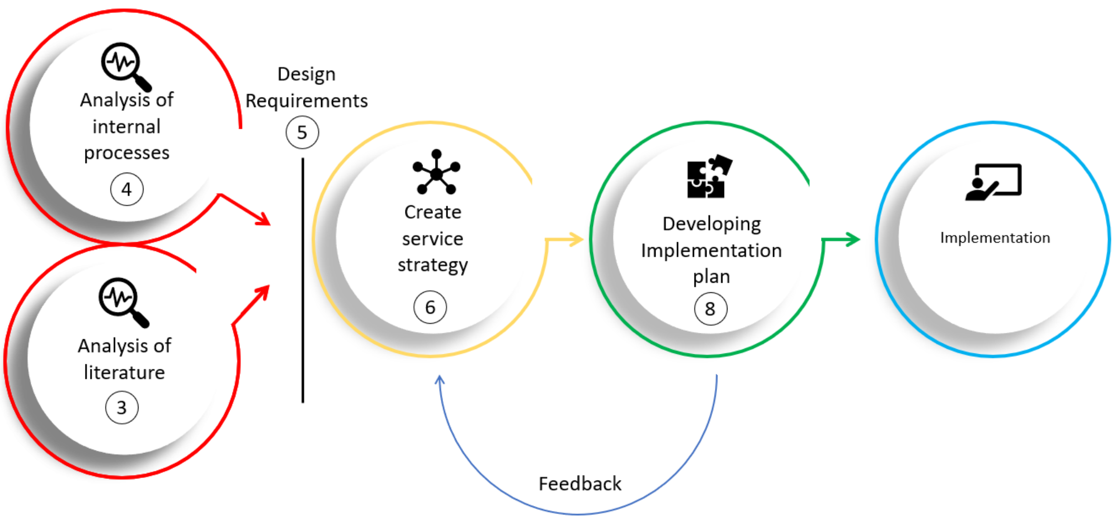

Figure 18: Design process, with chapter indications included, inspired by (Tschimmel, 2012) and (Li et al., 2020)

4.1 Company background

Royal IHC is a dredging company, founded in 1943. However, its roots go much further back than that. Shipbuilding company Smit, one of the predecessors of what currently is IHC, was already active in the dredging business in 1642 (*History - Royal IHC*, n.d.). IHC specializes in complex highly innovative dredgers, but also works in the offshore, mining and defense industries. In 2014, IHC Merwede received a honorary title from the King of the Netherlands, renaming the company to Royal IHC.

In 1963 Royal IHC introduced the IHC Beaver®, a standard cutter suction dredger(CSD). A CSD can be seen as a tool that is used to remove hard sediment from the bottom of a lake or river. Due to the fact that it is easily dismantled, transportation to remote or hard to reach areas is possible. Adding the fact that these standardized vessels could be created on a larger scale, the price is competitive all over the world. Over the years the design and performance of the Beavers has improved, but the philosophy on which they were build still stands. The amount of parts that are to be dismounted to prep the vessel for transport are kept to a minimum, in order to make life easier for the contractor throughout the vessel lifetime.

The unique selling point of the Beaver vessels is that they are build to stock, which results in very low delivery times, something that is rare in the maritime industry. Royal IHC is quite successful with the Beaver vessels, considering the estimated market share is between 40% and 50% in the non propelled CSD niche market. Non propelled means that the vessel itself has no ways to propel itself to or from destinations and will rely on other vessels for transportation.

Dredging deltas, keeping waterways at a certain depth, and preparations of bigger dredging operations are some of the main tasks that Beaver vessels will have during their lifetime. They are being used to create smaller harbors in remote areas but have also been used in big projects like the Panama and Suez canal.

4.2 Service of the vessels provided by IHC

On the services website (*Parts and logistics - Royal IHC*, n.d.), IHC is advertised as a one-stop shop for all parts. This includes predetermined prices and on-time delivery. There are also options for close cooperation in order to analyse which parts will be needed in any forthcoming period. There is a mention of guaranteed availability plus an option to make use of global stock locations. This would allow customers to always have access to their parts at the time they need them. In figure 19 the general workflow of current processes is displayed.

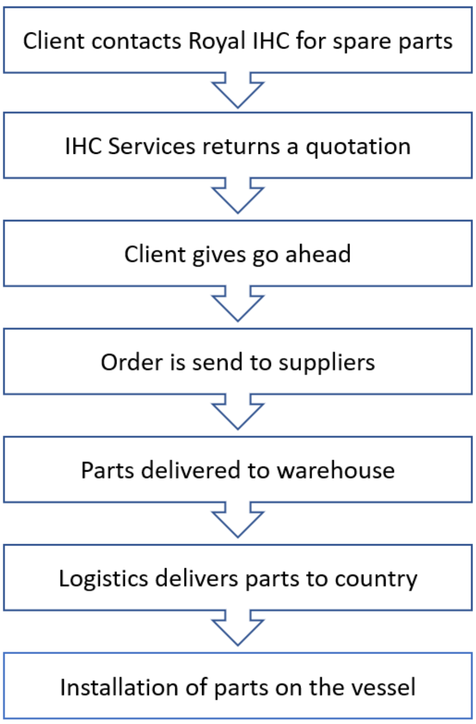

Figure 19: General outline of current service process (Order manager, personal communication)

Ideally one can assume that a smooth ordering process is followed up with spares that are of high quality, on time and within budget. Also known as OSBIT, this way of handling projects has been widely accepted within Royal IHC. These are the goals to aim for regarding service towards customers. This service can be seen as two components, first the initial interaction with the customer. Learning about their wishes and plans, while providing relevant and competitive products. The second part is after the deal is closed, the agreed upon parts are delivered to the customer on specification, budget and in time.

Making the deal

The first part of the service is where contact with the customer is made and maintained. Giving the customer relevant and competitive products is a good start, but not the whole picture. The previous experiences of customers also play a role. Just like a first interaction can make or break contact with a client. Having to navigate tons of phone calls, different purchasing orders and interaction with different people is not a process that can be experienced as smooth. This process can determine how willing customers are to back to Royal IHC for future services.

Honoring the agreement

The delivery part is all about the internal processes of the service business unit. These reflect on the delivery time and quality of the product. These are a big factor in how customers experience their service which in turn determines their willingness to come back for future service. Royal

IHC also offers customers a training for their personnel, this will prepare them for operational excellence and help them understand the vessel on a technical level.

4.3 Company transformation

Royal IHC is a company that operates with extensive knowledge in the dredging industry, this is what makes them an important partner for the biggest dredgers. Due to recent unfavourable financial results, a company downsizing and restructuring has been initiated. This restructuring will transform the old separated business units that operated very independently into a matrix structure where human resources are exchanged for projects and information should flow more freely between departments. This type of structure can be beneficial for companies that have diverse products or services. Interaction between people from different departments can provide a fresh look at the problem and stimulate innovation (*What is Matrix Organization?*, n.d.). Figure 20 shows the old hierarchical structure on the left, where the business units would operate independently and only report to upper management. On the right a matrix structure is shown, where people will be assigned to work on temporary projects outside their own department.

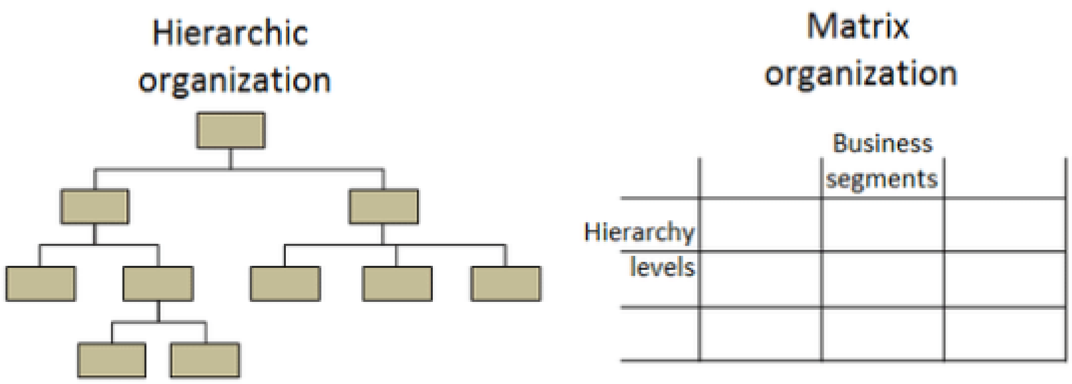

Figure 20: Transformation from a hierarchical structure to a matrix structure

Royal IHC also has issues in communication due to how the organization was structured historically. Before a big restructuring in 2020, the company was build up from different business units. These business units operated very independently and had, for example, their own HR and finance staff. After disappointing financial results in 2019, a restructuring was announced that would transform the independent business unit approach into a matrix structure as seen in figure 20. The matrix structure would have the benefit of integration between employees from different departments. The knowledge transfer and the understanding of activities outside the usual role of an employee were to create an environment where Royal IHC would become one company with a shared goal, instead of different business units under the same name.

Market uncertainty has plagued the dredging sector for the last two years, specifically tenders for the largest dredging vessels. Higher prices of both oil and building resources like steel have delayed up to, what Royal IHC management believes are, 25 major tenders for new custom-build dredge vessels. Historically Royal IHC would be in a good position for production of these vessels. However, almost all of these vessels are not being build due to uncertainty in the market from the earlier mentioned high prices in both oil and building materials. This drought of big custom-build orders is a big hit to Royal IHC, as almost half of the turnover used to be big custom-build vessels. This gap in turnover heavily cuts the revenue, while Royal IHC struggles to keep all experience in the company due to forced downsizing. For a company that identifies as market leader due to superior technical knowledge and experience in shipbuilding, losing these experienced employees can result in long term damage.

Creating an improved service structure is the main goal of this project. This improved service structure can result in new services offered to clients, but it can also point towards internal improvements. The multi-variable equation that is the base of maintenance service is dependent on factors that will be different, not only between sectors but even between companies within the same sector. For this project, the main factors that will play a role contain, the dominant position that Royal IHC has within this market, the extensive knowledge already within the company, the recent restructuring, and technical innovation.

The reason that the company transformation is highlighted is due to the underlying issues that were the cause for the transformation. Some of the problems that the transformation has tried to solve, still exist. The other reason for mentioning it in this thesis, is due to the fact that the situation the company finds itself in, creates additional limitations on the eventual design.

4.4 Installed base

Before diving into the numbers regarding the installed base, figure 21 is a picture showing the range of Beaver products from Royal IHC. From the Beaver 40 on the left, all the way to the Beaver 65 on the right. Not included in this picture is the Beaver 30, which was not in production at the time this picture was taken. The Beaver 30 has the same design as other Beavers but is smaller in general dimensions as well as pipe diameter. The pipe diameter is also indicated by the Beaver type. Beaver 30 vessels have a pipe diameter of 310mm, while Beaver 65 vessels have a pipe diameter of 650mm.

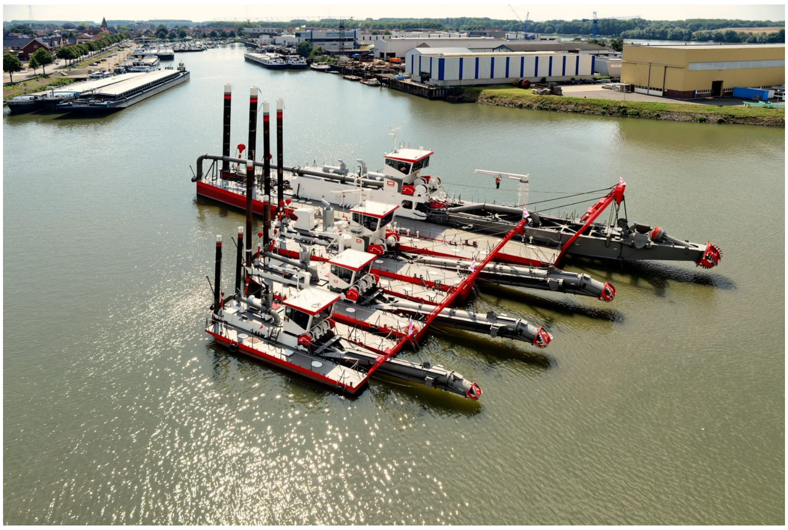

Figure 21: Overview of Beaver types

It is important to have an accurate selection of the installed base for the Beavers. This is due to the fact that the size and composition can provide relevant insights to certain initiatives. It also allows for a more specific recommendation that might only affect a certain type of Beaver. In an internal document, the current installed base has been estimated, shown in figure 22. The total of operational vessel per 08/06/2022 would amount to 484, consisting of 5 different standard types (Internal document, Royal IHC, 08/06/2022). It should be noted that not all of these vessels were sold as the type that they are listed under in this graph. Older models like the

Beaver 5014C are still around, 13 of them are included in this installed base overview. Due to the Beaver models being categorized by pipe diameter, this is also how older models have been included in the overview. This gives a clearer view of the total, since there are over 27 different types of Beavers that are still operational.

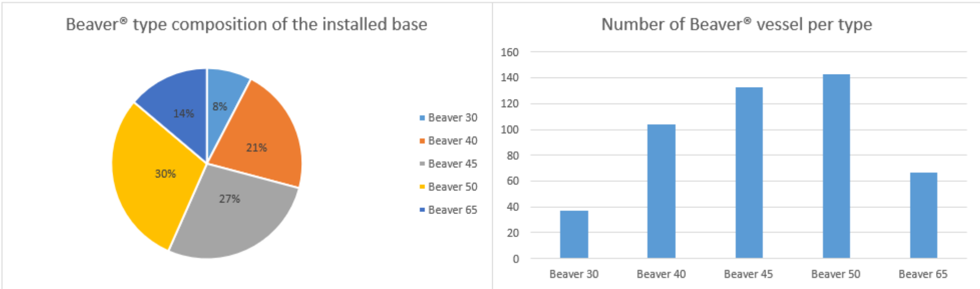

Figure 22: Installed base Beavers

The size and composition do not tell the whole story of an installed base. Most vessels have a lifetime of 30 years, this means that historical sales will be part of the current installed base for up to, and sometimes past, 30 years. Figure 23 shows the distribution of Beaver types sold per decade. In the left graph, the X-axis provides the different types of Beavers over the last three decades. The color of the bars is indicative of the decade in which the vessels were sold, blue being 20 to 30 years ago, orange being between 10 and 20 years and grey indicating the vessel was sold in the last decade. On the Y-axis are the sales numbers. This gives additional information, since it shows the total sales per decade. As seen on the left side of the figure, sales for the Beaver 40. Beaver 45, and Beaver 50 have increased significantly in the last decade compared to the decade before. The right part of the figure also shows that the distribution of Beaver types sold per decade has shifted. Over half of the Beaver 40 vessels that are currently operational were sold in the last decade. Whereas for the Beaver 30 only 20% of the current installed base were sold in the last ten years.

To get more of an indication of the price of these vessels, a standard beaver 30 will cost approximately €1 million. The bigger Beaver 50 will set you back approximately €2.5 million and the Beaver 65 costs around €7 million. With current spare part package prices ranging from €43.000 to €230.000 depending on the type of Beaver, the market for spare part packages in the last decade has a current value of €27 million. Important to note is that this number is only the initial spare part package and does not include any further spare part requests.

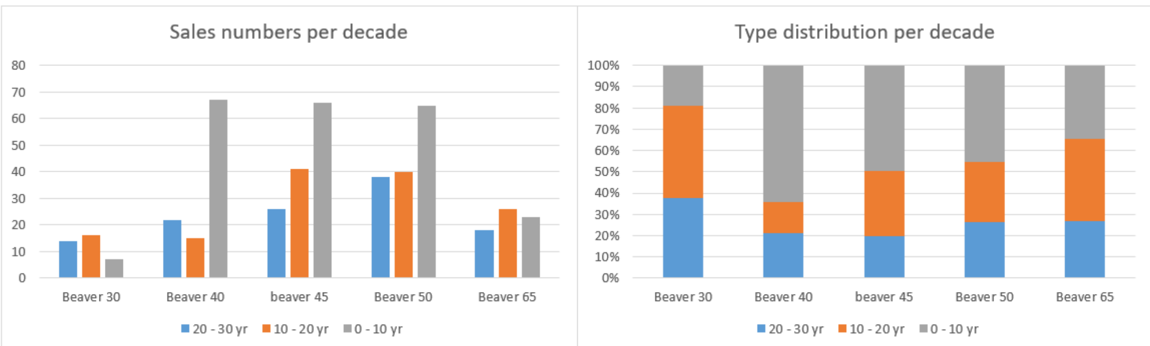

Figure 23: Sales numbers per decade, plus the type distribution on the total sales

This project will focus on the initial service package for new Beavers. The reason that a service design is created for new vessels, is due to the predictability and the clean slate to work with. Implementing services for operating vessels sold up to thirty years ago will create problems like information, technical issues and customers that are already locked in to certain processes that might be hard to convince. By choosing to use new vessels as a starting point for the service, Royal IHC can create the right environment in which the service is executed and contractual requirements under which they are valid. This does not mean that older vessel will always be excluded from this service opportunity, however the service should be rolled out on new vessels to determine the performance. Afterwards, the scope can be widened to also include already operational vessels.

Customer viewpoint

This project will focus om designing a renewed service for the Beaver vessels. In order to understand the customers needs, there should be an understanding of the customers goals. Production and availability are the most important ones in general. This means that efficiency and maintainability are important aspects towards reaching those goals.

Next to the goals, there are the maintenance options available to the customer. Beavers are build from a range of different parts of which are either obtainable via regular retailers like hardware stores, specialized equipment from original equipment manufacturers (OEM), which are available at these companies around the world. Lastly there are the parts that are Royal IHC specific and where Royal IHC is the only source of these parts, most dredging equipment falls under this category. This offers customers ranging options in maintenance, from available everywhere, to Royal IHC specific. These maintenance options from the customer should be taken into consideration when designing a new service, as the service should fill the need of the customer.

Geography is also an important aspect for many customers. many customers operate their Beaver vessels in remote areas. This is one of the advantages of the vessel, since it can easily be transported to places unreachable for other vessels. However, it can also present issues concerning supply chains or service providing.

Lastly, monetary and strategical choices of the customer should be taken into account. Some customers might be inclined to always choose for the cheapest option, disregarding logical arguments opposed to that. Other customers might be opposed to increased cooperation with Royal IHC in order to protect data they might perceive as sensitive.

4.5 Analysis of current processes

First, general information about the sales process will be shown, during which the role of Dredging Advisory Services is analysed. There will also be some details about the commissioning of the Beaver vessel that are shown. Thirdly, planned maintenance systems are analysed. Their current usage and limitations are explored, but also the potential for future improvements. A hardware breakdown structure is shown in order to gain insights into the classification of the spare parts. Afterwards, this initial classification will be used to explain the different use cases of parts and their role within the vessel. This concept will be explored further by designing a methodology that can identify any part within their maintenance environment. Since communication within different departments is important, a look within the company structure could point to problems and their causes. Following will be an analysis of ICT opportunities and their current restrictions. lastly, a stakeholder analysis is added.

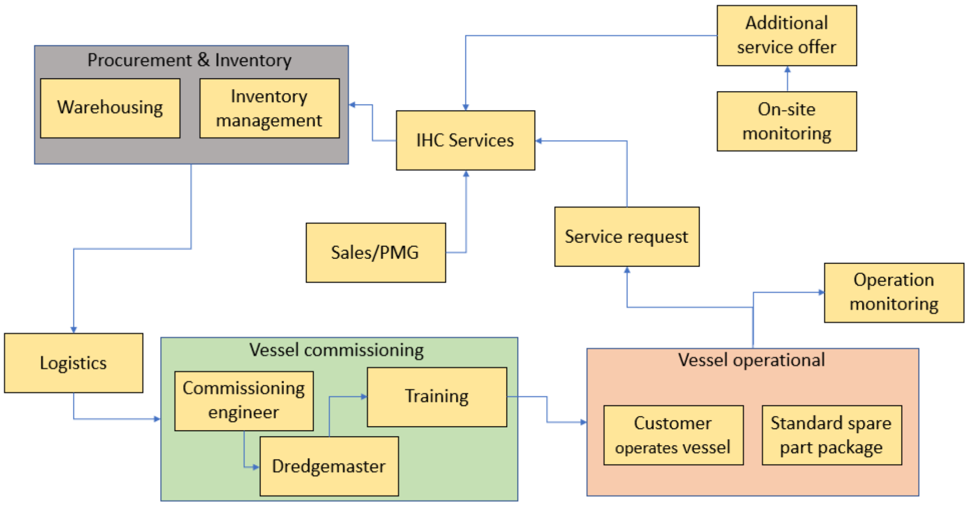

Figure 24: Existing service process

In figure 24, a general overview of processes and stakeholders within Royal IHC services is shown. More specifically, this chart can be interpreted as a flowchart that starts from the initial sales of a Beaver vessel and then follows a set of procedures and stakeholders to get operational. After the vessel is delivered and operational, after-service can be provided, of which the processes and stakeholders are indicated in the chart. During this chapter, all processes and stakeholders will be analysed to determine opportunities and to investigate weak links.

4.6 Sales process

This section will analyse the Sales/PMG box in figure 24. PMG is short for Product market group. Within Royal IHC, Beaver vessels are recognized as standard modular vessels, and therefore belong to the PMG SMV or Product Market Group Standard Modular Vessels. The blue arrow towards IHC Services indicates that information from the sales department and the PMG will flow towards IHC Services. In this case, whenever a sale is made, Royal IHC Services has to be informed in order to make sure that logistics, training, spare parts and after-service can be arranged.

Sales officers will be a major contact point for customers during this sales process. Backed by Beaver vessel information from the new-build section of Royal IHC. However, there will also be talks about the after-service and the capabilities of Royal IHC in that context.

Let's analyse what the advantages of a Beaver vessel actually are, as this is important to the sales team. Having a clear picture of what the vessel is capable of and the limitations it has will also be helpful to this project.

Beavers are a standard modular product and they are build to stock. Depending on the actual orders, the production can be increased or decreased of all Beaver types. A few years ago, over 100 Beaver vessels of different types were sold to a government. For this project, a lean manufacturing method was used taking inspiration from automotive manufacturers. 5 production lines were created in which the vessels were created in a sequential way. At the moment, production has been dialed down compared to that period. The fact that Beavers are build to stock is a unique selling point. Since the customer can use the vessel very quickly after the contract is signed. When a customer purchases a Beaver vessel, it will be commissioned and tested at Royal IHC Kinderdijk and shipped to the customer in at most four weeks. In those four weeks, the initial spare part package is prepared and loaded on board. This is done due to it being easier and cheaper regarding import costs. In that time, the color scheme for the Beaver can also be adjusted if needed.

The other advantage of Beaver vessels is that there are standard upgrades that can be fitted on the vessels. For example, anchor beams, booster stations or a spud carrier. All these extras can either increase efficiency, production or extend the operational range. For more information about the operational workings, Appendix A has the base operational information and additional details about available extras.

Dredging Advisory Services

In the sales process, Dredging Advisory Services (DAS), are sometimes consulted on technical aspects. They possess knowledge on technical aspects like soil conditions, cutterhead usage and estimated production. If a customer is interested in purchasing a Beaver for a specific project, or if there are certain projects that they want to do in the future, DAS can provide analysis on Beaver model and cutterhead choice. Due to the fact that Beaver vessels have a long lifespan, not only current circumstances but also future projects or opportunities have to be considered. All these elements can be analysed by DAS to create a complete report with recommendations to the customer.

The process mentioned above is quite intensive and requires a lot of resources from DAS. That is why such an extensive report is not done for all Beaver vessels, only sporadically. This is mostly due to the aforementioned time investment from the small team at DAS. The other reason is that the work from DAS is on behalf of Royal IHC and therefore not easily billable to the customer. DAS is working on an optimal solution for the customer, but the customer very rarely initiates the process of letting DAS carry out an analysis.

Instead of an extensive multifaceted report, DAS can also investigate cutterhead option, which largely depend on the soil conditions and the work that the customer expects. This analysis is much smaller in scope and therefore will not take up as much resources. The cutterhead is the part of a dredging vessel that is in direct contact with the soil. At Royal IHC and within the Beaver range, there are different cutterheads that can be mounted on a Beaver, depending on the environmental factors and the power levels of the Beaver.

Figure 25: Different types and sizes of cutterheads from Royal IHC

In figure 25, a range of different cuterheads is shown. These tools are used in order to scrape the top layer from the soil in order to pump it up. It is for this reason that the efficiency of this

Figure 26: A cutterhead with different teeth

specific tool is vital for the efficiency of the vessel as a whole. For the Beaver models, depending on the size and power available, sometimes a choice can be made between cutterheads in order to create a more efficient process for the conditions that are expected to be encountered.

The choice for a cutterhead is not the only vital choice. Having the wrong tools for a job will never create an efficient process and this is the same regarding the cutterteeth, shown in figure 26. A soil consisting of soft sediment like sand is completely different to a hard rocky soil. It is therefore only logical that the tools that are being used to remove this top layer are fit for the conditions that they will encounter. The wide teeth used for removing sand will get nowhere when they are used on a rocky layer, while tooth designed for rocky surfaced will be inefficient in sandy conditions.

Figure 27: Exploded view of the cutterhead and its components

For a smaller cutterhead, designed for the small Beaver models, an exploded view is provided in figure 27. All parts are welded together to create the final product, this included the teeth that are welded directly on the curved surfaces of the cutterhead. When new teeth are needed, the old teeth are removed from the cutterhead by grinding them off and welding a new set on. The Beaver 65 has a cutterhead with adapters between the cutterhead and its teeth. Specifically, the fourth picture in figure 25 shows the cutterhead with the adapters on which the teeth can be mounted, whereas the third picture is the same cutterhead with teeth mounted on the adapters. The difference between this and the smaller cutterhead is that this design offers the opportunity to replace individual teeth when they are broken or worn out.

DAS can provide recommendations with technical underpinning regarding cutterhead choice that is tailormade to the conditions the customer will encounter right away, but also future opportunities can be included. This is where the experience of Royal IHC can be used to assist customer with limited understanding of the subtle intricacies of dredging.

4.7 Vessel commissioning

When the Beaver is completed, it can be transported to the customer. Since Beavers are build for easy transportation to remote areas, multiple modes of transportation are possible. The smaller types can be put on trucks or trains and transported that way, whereas the bigger Beaver 65 needs to be transported by ship.

When the Beaver arrives at the customer, it needs to be recommissioned. This means that a commissioning engineer from Royal IHC will make sure that the Beaver is put back together with full functionality. All Beavers are commissioned at Royal IHC before they are shipped towards the customer, in order to guarantee full functionality. However, for transportation the vessel is disassembled after which it should be recommissioned when arriving at the customer. After the vessel is fully functional, a dredgemaster will visit the customer. For a month, he will teach the crew how the vessel is operated and all aspects that the crew need to understand in order to handle the vessel themselves. This training is provided by the training institute, a part of Royal IHC Services.

When the dredgemaster has completed the training, the crew should be able to operate the vessel without issues and the customer can begin with their projects. It is at this moment that the initial support from Royal IHC historically ends and initiative from the customer is needed to provide additional service.

4.8 Planned maintenance systems

Within Royal IHC Services, planned maintenance systems is the group that designs the structure in which the customer can perform their maintenance. This department is relevant for this project due to the possibilities of extended service that can be created. If a good enough picture of maintenance needs can be created, this can be turned into a maintenance service.

4.8.1 Fleet management system

New vessels can come with a fleet management system called Marad, from the company MaraSoft. Within Marad there is information on every part of the vessel and its specific maintenance need. Royal IHC receives an empty canvas in Marad for each new vessel, which they fill with all relevant maintenance information. This includes regular maintenance tasks that are to be performed by the crew at certain intervals. For example, the oil needs to be refilled every 500 hours, plus the filters need to be replaced at the same time. After the task is done, it can be assigned as completed by the customer in Marad, visible for both the customer and Royal IHC. There are also operational booklets, crew requirements and safety procedures stored in the system.

4.8.2 Operational monitoring

Royal IHC uses E-won in order to gain insights in the operation of the Beaver vessels. Data like speed, operating hours and RPM are saved. This data is available to both Royal IHC and the customer. At the moment this data can be used to help customer when they have problems, for example with their production. At Royal IHC, someone can look at the data and see if there is a pattern that indicates an opportunity or misuse of the product.

At the moment it is not possible to use this data logger to gain insights in the condition of parts of equipment. This is due to the fact that the frequency that the data logger uses is low. It is therefore not possible to notice indicators of damage like vibrations in the engine or pump. However, Royal IHC does have equipment to measure equipment and gain data insights if they are on board of the vessel. The disadvantage of this is that there needs to be a crew deployed to the customer with the needed equipment. Data can be analysed at Royal IHC to find the problem with the vessel. Due to the fact that Royal IHC builds these vessels for a long time, the underlying issue is often clear from these measurements (Operations monitoring specialist, personal communication, 09/05/2022).

4.8.3 Challenges

This monitoring also presents a couple of challenges. One of the maintenance tasks is checking the condition of the v-belt of the engine every two months. There is little control or insight into whether this task is actually performed or if it is simply crossed of without checking. This presents problems for monitoring due to the fact that the information that gets to Royal IHC might not be fully accurate. Ultimately, the customers determine if and to which degree these tasks are done and reported. This leaves Royal IHC in a position where the actual state of the vessel can be quite different compared to the information available at Royal IHC.

Another example is the measurement of the pipe diameter, which needs to be done every month. The reason is that due to the rough conditions of sand getting pumped trough this pipe, it is expected that the diameter increases over time. Indicating that the pipe is experiencing wear due to the damage the coarse sand does to this piece of equipment. In reality, a project in Jordan experienced nearly no wear in the pipe in half a year. The reason was due to the highly saline conditions of the sand leaving little wear in this specific part. However, it did lead to the crew becoming complacent and not performing and noting the maintenance task, since in their experience it did not matter because there was no difference (Planned maintenance systems engineer, personal communication, 21/04/2022).

There is also the fact that in Royal IHC's experience, many beginning dredgers in less developed countries, which is a big part of the market for Beavers, find the process of doing and logging maintenance a bureaucratic process. Leading to little maintenance information getting back to Royal IHC concerning the maintenance needs or problems. Clients buy the vessel and operate it until there is a problem leading to an operation stop, it is at that moment that communication with Royal IHC starts again. It is important to note that this is not the case for every vessel, but it is something that happens regularly.

Currently, the Planned Maintenance part of Royal IHC that works on Beaver vessels is creating a service bill of materials (SBOM). There are a couple of reasons as to why this is more complicated than anticipated. The different types of Beaver vessels do not share as many parts as would be ideal. This amplifies the amount of different products that need to be serviceable, since different Beavers need different versions of the same part. At the moment, approximately over 80% of serviceable parts is different across the different Beaver types.

There are also engineering advancements that increase the performance of Beavers, these changes impact at the least a couple of serviceable parts. This creates complications due to the fact that throughout the years, newer models are equipped with different parts. An addition to this is the fact that sometimes Royal IHC changes of supplier for certain parts. There are also vessels that are customized for specific use, which changes the parts in the vessel.

This creates a complex picture of parts needed for each specific vessel. Parts of the vessel will change based on type and building year. Adding to that, changes in suppliers can change the part list from vessels of the same type that have the same building year. The last factor is that customized vessels will obviously also have certain different parts.

4.8.4 Opportunities

There are a couple of takeaways for service enhancement opportunities in this area. Planned maintenance systems allow both the customer and Royal IHC to have an overview of the maintenance a vessel requires, this can provide valuable information in order to keep a vessel available for production. For the customer this increases up-time, whereas for Royal IHC it increased knowledge of the wear of the product and its parts. It also give Royal IHC the opportunity to better inform the customer of maintenance opportunities in order to keep the vessel in an operational state.

In the ideal scenario, customer have access to e-won. They can interact with the software to announce a problem, receive an accurate price list and IHC service will contact them with a proposed service date. This thought resonated with multiple people within the service organization, however, the service is not at that point yet.

Currently, there are mainly information flow issues that withhold Royal IHC form this ideal scenario. The information about the maintenance activities from the customer can not always be depended upon. Accurate prices of parts are not actively shared with customers and only provided when a service request has been received from a customer.

4.8.5 Limitations

At the moment, with the way how Marad works, Royal IHC is very dependent on the customers to engage with the program in order to stay in the loop with the maintenance needs of a vessel.

It is hard to accurately predict the maintenance needs of a new vessel, because Beavers are deployed in such diverse environments. It can take up to a couple of years to get a picture of the exact needs of a vessel regarding wear parts like the cutterteeth.

It remains unclear what the definition of a critical spare is. Determining which parts are critical does not follow from sound methodology, but is currently determined without clear reasoning. This is important because critical parts should be part of a service package. Critical indicates that a failure of the part will stop any operation of the vessel until a replacement is installed. A part can be critical due to the fact that without it, operation is impossible. However, a long lead time for a certain part could also be the reason for it being labelled as critical. Failure mode effect & criticality analysis is a way to gain insights in the criticality of spare parts in a package.

4.9 Fleet management & Service contracts

There is a lot of knowledge within Royal IHC regarding maintenance and this might be applicable to Beaver vessels. If the goal of this project is to increase customer retention, increasing cooperation with customers in the maintenance of their vessels is important. This would increase service level perceived by customers and could provide more reliable revenue streams for Royal IHC. During this project, Systems engineering and analysis by Blanchard and Fabrycky will be used (Blanchard & Fabrycky, 2011). They have extensively documented service and maintenance on complex systems, which will be useful in the context of this project.

A performance service contract is useful in situations where performance is easily calculated or determined (Horenbeek & Jordan, 2012). In dredging, production, up-time and vessel availability are metrics that accurately reflect performance. Therefore, this could be a direction worth exploring of future service.

Royal IHC currently has a full service contract in Jordan. This deal consists of the production availability of 3 Beaver vessels, two customized Beaver 65's and one beaver 45. These vessels operate 24/7 and Royal IHC is responsible for the up-time and availability of the vessel.

In order to carry out all required maintenance, the Jordan operation uses Marad software to track everything. Marad will indicate all regular maintenance that is needed depending on either production volume or production hours. If certain maintenance is done on the vessel, it can be registered in Marad, which will process the data and recalculate the next maintenance.

The manager of the Jordan operation explained that maintenance is grouped in order to prevent unnecessary downtime. Every 1000 hours, the oil from the main engines need to be changed. Since the vessels operate 24/7, this is approximately every month and a half. Since there is 1400 liters of oil in the Beaver 65 vessel, this will take multiple hours. First the oil needs to cool down, which takes up to two hours. After the oil is cooled down the old oil needs to be pumped out and afterwards the new oil needs to pumped in. During this forced downtime, all other small maintenance needs of the vessel are being executed.

The other big maintenance moment is at the 9000 hour mark. This is when the engine gets a big overhaul, which takes around two to three weeks. During this time period, all bigger maintenance jobs can be executed parallel to the engine work. Think about welding work on the cutterhead, overhauling of winches, and repairing the spud poles. The cutterhead for the bigger Beaver vessels Whereas the smaller Beaver models have the teeth directly connected to the cutterhead, the cutterhead of a Beaver 65 is larger. Instead, adapters are welded on the cutterhead, these adapters then function as a base on which the individual teeth are placed. During the maintenance these teeth and also adapters can be replaced if needed. The spud poles, the two poles on the back of the vessel, which allow for the forward movement, can also be repaired. Possible malfunctions are damage to the cylinder which creates leaks, or wear in the locking mechanism that is causing further damage to the surrounding parts.

The circumstances of 24/7 operation and the environmental factors of dredging very saline soil are unique at the moment. However, so far, this program of maintenance has achieved excellent results with vessel up-time at 92%. The experiences of this project can be used in the new service design. Since Royal IHC is 100% responsible for maintenance on those Beaver vessels, a very complete picture can be created of the maintenance needs of the vessel during the first part of its operational lifetime. The experience of doing scheduled maintenance during the changing of oil and overhaul of the engine can be used in other Beaver vessels as well.

4.10 Operational profiles

Royal IHC works with EWON software, this allows Royal IHC to gain insight in the use of Beaver vessels. The software allows for easily accessible information sharing which can be used to improve our service. A possible recommendation could flow from this accessible usage data. If a complete enough picture of the usage of the vessel can be created with the data available, that would allow Royal IHC to compare this to the maintenance that the vessel has received. It might be possible to gain insights in performance indicators that originate from common problems, which might be prevented by maintenance (Blanchard & Fabrycky, 2011). It is to be seen in what capacity this is possible at the moment, but a strategy could be created to make this a possibility in the near future.

In the literature, this usage of operational profiles has been used to predict maintenance. The ability to gather data from a large group of similar vessels could translate into data about operational profiles. Royal IHC does have the installed base in its Beaver range to really research the operational profiles, which could result in better maintenance advice.

A challenge that presents itself is the fact that all the Beaver vessels operate in their own environment. Where Killeen et al. (2019) was able to determine the operational profile of a fleet of busses, this was partly made possible due to the similar conditions each bus operates in. Customers of Royal IHC are operating all around the world in different environments, doing different projects, and have different operator skill levels. While creating a hurdle to perfectly ascertain the operational profile of each individual Beaver vessel. A more general operational profile could be established based on a region or dredging environment.

4.11 Stakeholder analysis

The goal of a stakeholder analysis is to find out what challenges can be expected from the involved stakeholders. Also, it might give an indication as to the behaviour of certain stakeholders towards the proposed changes of this project. Knowing their stance towards the implications of the project can prove useful because it can be taken into consideration before interacting with those stakeholders. Potential cooperation can be used as an advantage whereas potential threats can be dealt with accordingly Savage et al. (1991). In figure 28 an overview of the most important stakeholders is shown.

The stakeholders are categorized in two different groups, internal and external. Internal stakeholder in this case belong to the organization or subsidiaries of Royal IHC. External stakeholders are clients of Royal IHC and the government. The government has influence on the decisions made within Royal IHC due to existing and future laws. If for example trading with certain countries is restricted, this will certainly have an impact for Royal IHC, which operates all over the world.

Front office (Service)

The front office consists of sales personnel that interacts with the customer whenever needed. If a part need is brought to their attention, they are the ones to initiate the service process by defining the scope, which is handled by the back office after it becomes order. More precisely, it is their task to work with the client to determine the exact part or assembly that is needed. They initiate requests for quotations at suppliers if prices are unknown or expired in ERP system

Internal stakeholders	
Front Office	Warehousing
Back Office	Finance
Engineering	Logistics
Maintenance crews	

External stakeholders	
Customers	Government

Figure 28: Internal and external stakeholders.

and in case of a make part they request a price (calculation) at the responsible IHC make department based on this a price indication is given based on which the client can give the go ahead.

An overhaul of the service package will influence what colleagues of the front office can offer to customers. If this project recommends a type of service opportunity that requires a different process, this will impact how their work is being done. The way this is perceived will determine if resistance or cooperation can be expected.

Back office (service)

The back office manages the internal service processes. There is interaction with suppliers, logistics and maintenance crews in order to fulfill the service needs of customers. Once an order has been placed, these employees will handle the sourcing of the parts or assemblies. Trade parts, which come from third parties require contact with suppliers, while parts that are made within Royal IHC or its subsidiaries require internal communication.

This stakeholder has both high power and high interest, which means that it needs to be closely managed. At the end of the day, this is where the project originated and also where the decision will be made to execute the results, in part of wholly, or not. Changes to the service design can directly impact the way people work at the back office, meaning that this stakeholder needs to be involved with the project to make sure that the project is relevant and that there are no surprises in the end.

Clients

The clients are a crucial part of the process. At the moment they take the initiative, by contacting Royal IHC, in case of maintenance needs. Communication with the front office translates their wishes to actual service or product needs. The clients have high interest, but minimal power. It may seem counter intuitive that in a service that revolves around the perceived value of the customer, the customer has no power. Yes, the customer has power over their decision to do business with Royal IHC, now and in the future. But, no actual power in the process of improving the internal processes and types of service that is being developed at Royal IHC. Since they are the customer, it should be of the utmost importance that their needs and wishes are met, which should be the aim of the improvement in the first place. Therefore, it is important to find out how exactly our service could add more value to our customers. During this project it would be great to receive this kind of information in order to create relevant recommendations.

Maintenance crews

Stationed around the world, plus a couple of dedicated deployable crews, IHC has the ability to provide service all over the world. This service is not limited to Beaver models in particular, however they are included in the overall maintenance programs.

Finance

Finance has a stake in the Beaver maintenance operations due to the cost aspect. Spare parts need to be sourced which required financing. If there is no immediate use, but parts are bought to have inventory, finance will want to be included in the decision on how much inventory is needed. Since resources tied up in inventory do not have a direct use and only serve as potential future income.

Logistics

Logistics are at the end of the provided service. Together with the client, a decision will be made where the spare parts are handed over. This can be at the nearest air- or seaport, shipyard, or to the vessel itself. The sourcing of the initial spare parts to IHC is often the responsibility of the supplier, which eliminates heavy involvement of logistics from IHC.

Warehousing

Just like money, inventory space is a finite resource. Especially with Royal IHC's worldwide client base, relevant inventory that is accessible in a timely fashion can be hard to manage. If the service is expanded or extended, this might cause resistance to change due to the extra load. The end goal is to become the trusted partner

Engineering

The engineering department has two ways of interacting with spare part service. The first one is whenever they finish a certain engineering project for a vessel. Decisions need to be made about which parts will become spare parts which requires some extra attention. The second way is when a customer requires a certain spare that is not available, either because they have modified it without help from IHC or because the part is too old and not used as a spare any longer. This requires engineering to be done in order to create a spare that adequately replaces the current part.

In order to easily identify important stakeholders, a power interest grid is constructed. In this grid, stakeholders are assigned to one of four zones, depending on their power and interest in the project Mendelow (1981). Stakeholders with low power and low interest are to be monitored, but do not require heavy management. Contrary to stakeholders that have high power and high interest that need to be managed very closely, in order to create a relevant and workable solution. The square with high power and low interest will not directly create resistance towards the project as long as their requirements are satisfied. Lastly, the square consisting with stakeholders that have high interest and low power. These stakeholders are to be kept informed in order to keep them satisfied.

Engagement methods

From figure 29, the following conclusion can be taken. The front and back office are very important stakeholders, since both have high power and high interest. During this project, communication and interaction is therefore needed in order to keep these stakeholders satisfied.

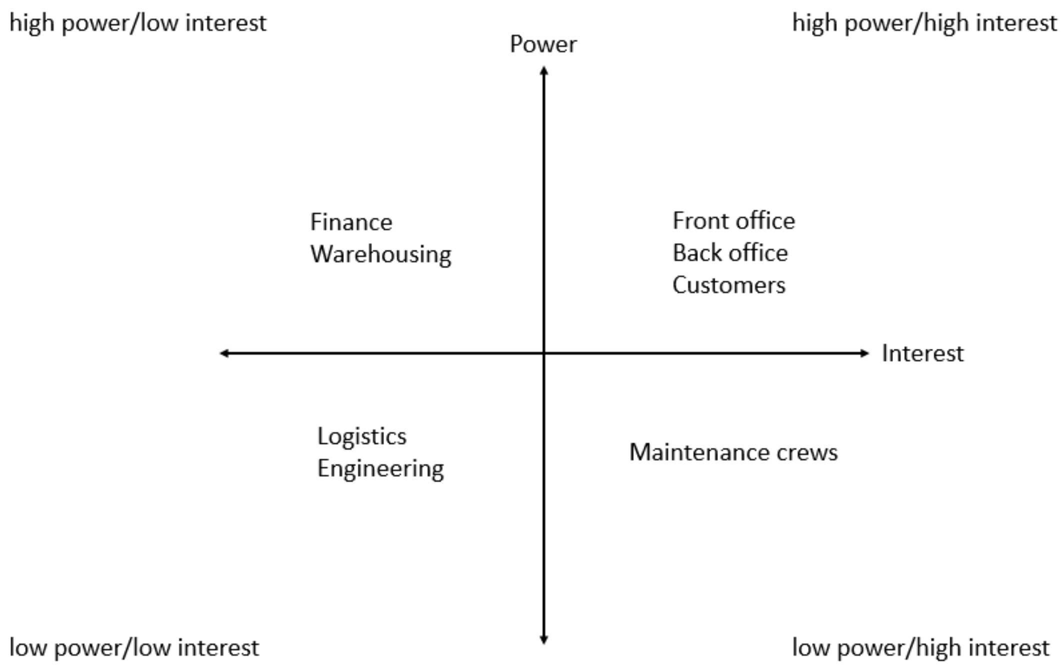

Figure 29: Power-interest matrix (Mendelow, 1981)

In order to keep these stakeholders engaged, a meeting every two weeks is organised. During this feedback session, progression is shared and feedback provided. Clients also play a pivotal role since their satisfaction is the key to success for Royal IHC. Specifically, the satisfaction that they experience in the whole service process will determine how likely they are to return in the future. In order to get the insights from customers on the proposed changes, a feedback moment has been planned. It consists of questions regarding the current process and asks for feedback on the proposed changes. This feedback moment will be done with 15 current customers that are in possession of at least one Beaver vessel.

4.12 Hardware Breakdown Structure

Since this project is based in a complex and high tech environment, there are many moving parts that contribute to each vessel. These very specific technical parts create unique vessels with characteristic abilities. To gain insights into the make up of the vessel a Product Breakdown Structure (HBS) can be created. A HBS is used to show a complete overview of all parts and their place within the product (Bai & Bai, 2010). The HBS is a variant of the more well known work breakdown structure(WBS), but instead of grouping all tasks that lead to a goal, all parts of the product are grouped. The goal of this HBS is to get a hold of the different types of spare parts that exists within the Beaver vessels. If a clear picture of these types of spare parts can be created, conclusions can be made on that information and used in the design of the spare part package.

4.12.1 Maintenance parts classification

The current spare part package can be divided in five main types of parts (Royal IHC, Internal document, 28/05/2021).

- Wear parts
- Consumables

- Capital parts
- Programmed parts
- Obsolete parts

Consumables parts include, but are not limited to, rubbers, hoses, etc. These parts are not Royal IHC specific and are available world wide at local OEM dealers. OEM is short for Original Equipment Manufacturer, which indicates that the parts come from certain preferred dealers and are afterwards combined to the end product. The experience at IHC Services is that customers usually buy these parts locally instead of contacting Royal IHC. The logic behind this is that these parts are often low cost and importing them cost more money and time. This experience is underlined by the policy regarding these spare parts. Aftersales of these parts are typically reactive, meaning that parts are only ordered after a customer asks for them. This is possible due to the fact that OEM parts usually have low delivery time, meaning that having stock is not necessary. An example of this is found in the engines that power the operation of the vessel. The engine and its components are from Caterpillar, which operates all over the world. With the engine type number, clients can easily inform at Caterpillar about a spare part within the engine, and source it from their nearest location. This turns out to be cheaper than using Royal IHC as a middleman, which is why these requests do not happen very often.

Spare parts related to wear include parts like rubbers, cutter teeth and parts of the dredge pump. Their main characteristic is that they continuously move during operation, or are exposed to moving sand or other types of soil. These parts should be replaced once their maximum amount of operational hours has been reached, to prevent hazards. Further research could indicate if there are opportunities for service of these parts. The fact that they have a maintenance schedule dictated by operating hours might open the door for planned maintenance. This can be attractive for companies that are inexperienced with dredging and its practices regarding maintenance, or companies that rely heavily on maximum operational up-time (Order manager, personal communication, 02/03/2022).

As the name suggests, capital spares are the most expensive parts of the current package. These are parts like cutter heads, heavy and expensive parts that are made by subsidiaries of Royal IHC, or preferred partners. These parts are mission critical, in this case meaning that a failure with these parts will result in prolonged disruption of operation. This prolonged disruption is often caused due to long lead times for the specific parts. The transportation and installation of the parts can also add to this disruption. Customers have to return to Royal IHC Service for these parts, due to their importance and the fact that they are exclusively available via Royal IHC.

Programmed parts are the so called Programmable Logic Controllers (PLC). The function of this part is to translate an input to an action. For example, pressing the "lowering" button will lead to the cutterladder lowering. The software behind this translation is proprietary of Royal IHC, legally it can only be repaired by Royal IHC in case of a failure. This software is rarely customized and historical data indicates that it rarely malfunctions, resulting in a low amount of maintenance requests.

Obsolete parts are the last category of spare parts. In this context, obsolete parts are parts that are equipped on a vessel, but not serviceable any longer. A potential cause is that a supplier stopped manufacturing of the specific part. In the case of obsolete parts, Royal IHC offers engineering services that will find solutions for fitting spare parts.

Royal IHC has a high added value for wear, capital, programmable and obsolete parts (Beaver specialist). As mentioned before, programmed parts very rarely require maintenance and are therefore not a large part of the equation. This leaves wear, capital and obsolete parts for the main added value for Royal IHC.

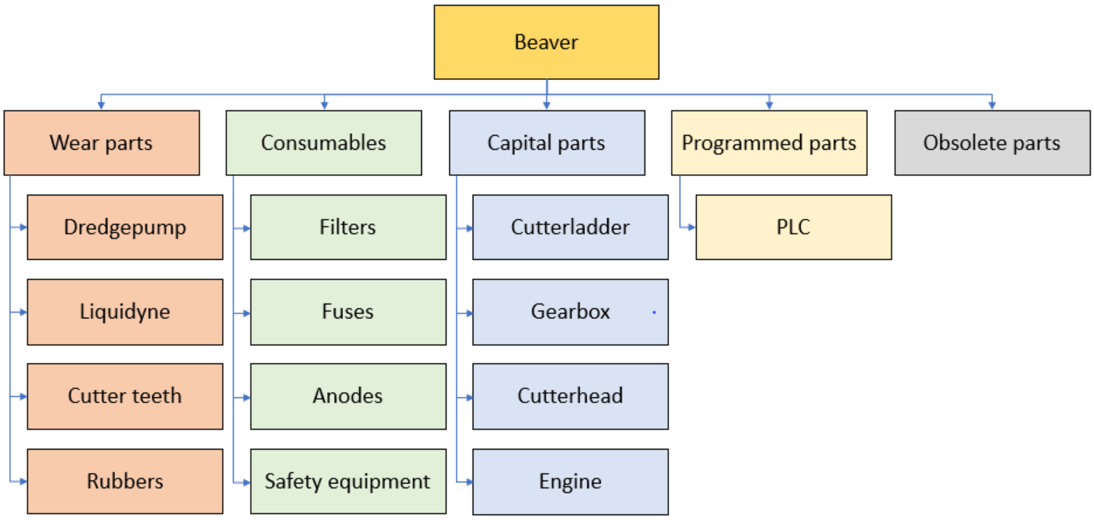

Figure 30: Hardware Breakdown Structure for the current spare part package of Beaver vessels

In figure 30 a reduced Hardware Breakdown Structure is shown for Royal IHC Beavers. The complete make up of technical parts within the spare part package is extensive and does not fall within the scope of this project. However, the figure will show the five categories mentioned in chapter 4.12.1, with examples of spares that fall under that category. This figure should give an indication as to what kind of parts belong to each category and by no mean offer the very extensive list of available spare parts.

4.12.2 Considerations in the spare part package

The distinction of the different categories is important when determining the spare part package for new vessels. Wear parts must be included since they need to be replaced due to wear, this can be determined by comparing expected operational hours of the vessel with the life expectancy of the wear parts. Not only operational hours, environmental conditions and the skill of the operator will also play a role in the rate of wear. Capital spares on the other hand are often expensive and are not expected to fail in the first years of operation. This is a difficult situation because customers are often tied to a certain budget which does not allow for expensive capital spares. However, as mentioned before, whenever such a part does fail it can have a huge impact on the operational ability for quite some time. This situation does offer an opportunity to Royal IHC, since the dependency of customers on these parts is very high and their alternatives are very limited. It can be interesting to look at this dilemma and see if there as a service that Royal IHC can offer to customers. Think about a monthly or yearly fee in exchange for the ability to buy and install these expensive parts in a timely manner. This would give the customer the insurance that critical and expensive parts can be replaced without too much disruption. It would also give Royal IHC the financial flow to actually buy and store these parts. This idea will be explored further in chapter 6.

Another observation in the current standard spare part package concerns the lack of distinction between operational environments. Whereas the word "standard", in standard spare part package, implies a non-customizable package that functions as a one size fits all, practically this is not how it works. Due to the very different environments that these vessels operate in, their expected wear can be completely different (Regional manager, personal communication). If more focus on customer satisfaction is the goal, serving the needs of the customer becomes a priority.

There are a multitude to variables that will impact the choice of cutter for a dredging vessel. The type of soil is important, operator skill level, and the salinity has to be considered as well. At Royal IHC there are 5 defined types of soil, ranging from sand to rocks. The first three categories are shown in figure 31, being sand, clay and silt. It can also be seen that there is much overlay between the types of soil, 40% clay and 60% silt will have different characteristics than just clay or silt. These different characteristics will also influence the rate of wear in specific parts. The last two categories are gravel and rock, where the rock category has several sub categories depending on the compressive strength of the rock.

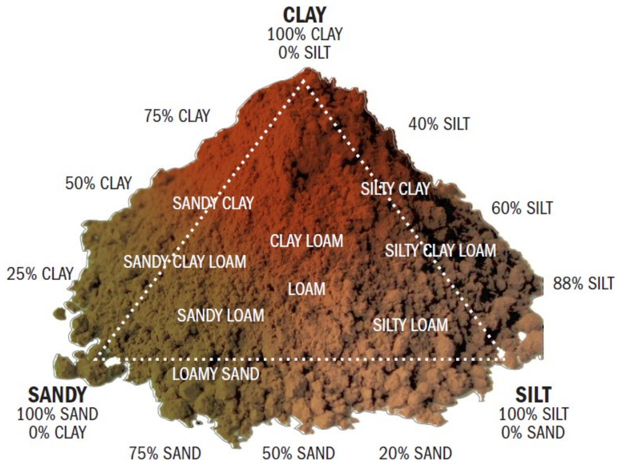

Figure 31: Interaction between sand, silt and clay in soil composition (Balas et al., n.d.).

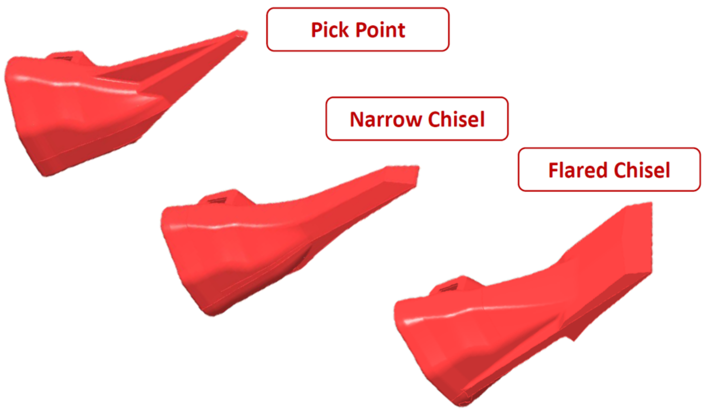

Figure 32: Different types of tooth that can be fitted on the cutterhead.

The cutterhead and its teeth have different designs, based on the soil that the customer encounters. For soft soil like sand, a wide teeth is optimal. Whereas a soil that has hard contents like rock, a tooth will have the characteristics of a sharp pick-axe. In figure 32, this is shown graphically. Another possibility is a muddy soil, which can provide difficulties due to the fact that the soil will stick to the cutterhead and its teeth. These examples show both the high tech engineering that Royal IHC provides and the completely different environments that these dredging vessels might encounter. Which brings back the situation mentioned before, because how can a standard spare part package be aligned to the needs of every customer if every package provides the same parts in the same quantity regardless of the operational environment.

The situation of different equipment for different conditions has to be reflected in the composition and number of spares of the spare part package. The composition part of the spare part package should therefore follow from the type of soil the customer expects to encounter. The number of parts are also dependent on the environment where the dredging is done. Wear of the cutterteeth is significantly higher in a hard, rocky soil compared to a softer soil, like sand.

In order to create a spare part package that can be matched to the needs of customers, these different dredging conditions need to be quantified. Initially, historical data can provide an estimation of wear in the specific parts. However, this can be continuously improved upon by updating these numbers from feedback of vessels operating in similar conditions. This way, a customer does not use two year worth of wear parts in the first couple of months of operation, a situation that happens occasionally (Regional manager, personal communication).

4.13 Renewed classification of parts

In this section, definitions will be explored in order to clearly label individual spare parts in categories that make sense from a maintenance standpoint. The maintenance standpoint is used because of the fact that the customer retention is the overall goal. Apart from the performance of the vessel, maintenance will be an important share of the satisfaction that the customers experience. Therefore, the categories will be defined in such a way that the categories reflect the type of maintenance that the vessel requires. Historically the classification has been done from experience and engineering standpoints. Whereas experience is valuable and the engineering classification makes sense initially, the maintenance in the after sales process will put the focus on different elements. These different elements can be grouped under different categories that create a better system in order to increase the performance of the maintenance program.

As mentioned before, the current spare part package consists of many different high tech parts. The analysis made a distinction between the five most important groups of parts, as they are classified right now.

- Wear parts
- Consumables
- Capital parts
- Programmed parts
- Obsolete parts

In chapter 4.12.1, a more detailed explanation is offered towards these current classifications. One of the conclusions was that wear parts have to be included in the initial spare part package, for the simple reason that operation of the vessel would stop due to worn out parts.

Two questions need to be answered in order to create a fitting and relevant spare part list. The first question is regarding the definition of critical spare parts and its implications. The second question concerns the quantity of certain type of parts that are to be included in the initial spare part package. The following section will give a structure that can be used to create a fitting spare part package for customers.

An important part is to clearly define the parts from a maintenance point of view. Parts can have multiple labels assigned to them, for example, a part can be a wear part but also be part of regular planned maintenance. Special attention will be given to the term "critical spare", at the moment this term is used without a clear definition. It is a combination of experience and intuition, which can lead to confusing situations both at Royal IHC and for the customer (Maintenance manager, personal communication, 17/05/2022). There needs to be a clear definition for critical spare parts. This definition list does not go into detail on specific parts, however all parts should be able to be assigned to their corresponding label when consulting the chart. This figure in general is not only applicable to Beaver vessels, but any dredging vessel that is build by Royal IHC.

The categories and definitions for all types of parts are shown in the list below. These classification came from a group discussion between different departments in the service process. There are still five categories, however some distinct differences can be seen. The term capital spare has disappeared, however the parts that fall under this term can be assigned in the new categories. Many of them are either expensive wear parts or expensive critical spare parts. The difference being if they show wear or not.

- Maintenance planning parts
  - Preventive: parts and consumables required for preventive jobs. (based on fixed interval
  - Condition based: parts and consumables required for condition based jobs (e.g. by inspection or monitoring system)
- Wear parts
  - Based on (estimated) operational conditions
- Critical parts
  - Parts that typically do not show wear and tear, yet can break down and do require replacement to maintain operations/performance
- Non-critical parts
  - Parts that typically do not show wear and tear, yet can break down without directly impacting the ability to operate the asset
- Structural parts
  - Parts and structural elements, that typically do not show wear and tear, neither break down during normal operation. It may for example damage due to an accident or improper usage of the asset

The first category, maintenance planning parts, has been created in order to easily identify parts that should be replaced on a certain interval. This can be due to two reasons, the first being preventive. This is when parts have a certain maximum amount of operational hours or production quantity, after which they should be replaced. The second part is condition based, parts that need to be replaced when they have deteriorated to a certain point, which can be observed either by monitoring or inspection. The reason that maintenance planning parts have their own category is due to the fact that it indicates to both the customer and Royal IHC that such a part will be needed regularly and can be provided by maintenance services.

Wear parts still have their own category, since it is the category where Royal IHC has the most added value. Specific parts that Royal IHC has the rights to, which need to be replaced due to wear of the part in the operation process.

Critical spares are parts that do not fall under regular planned or condition-based maintenance, however they are critical to the operation of the vessel. contrary to category 4, which are similar parts however they will not directly impact operational performance. As mentioned before, this criticality can be assigned due to multiple reasons, which can be different for each person in the service process, including the customer. Therefore, in section 4.13.2, a more structural definition of the term criticality is given.

The last category will house parts that are not included in other categories, mostly due to the fact that they are not considered regular spare parts. These include structural parts like the hull of the vessel, which in very rare cases can get damaged. The hull is not a regular spare parts, however it is classified as a structural part which can be repaired or provided to customer if needed. In practice this category will get the least amount of service requests.

4.13.1 Critical parts

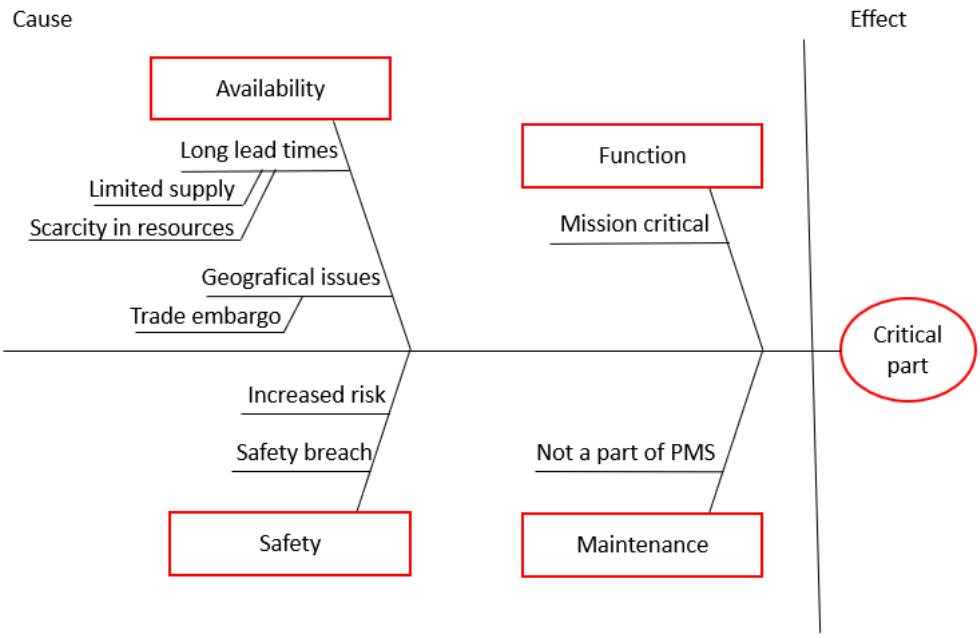

Figure 33: Fishbone structure for cause-effect analysis of critical parts

Ishikawa has introduced the Fishbone structure as a tool to identify cause-effect (Ishikawa, 1986). In figure 33 a fishbone structure is used to determine what factors make a part critical. This figure has been created by the author, with confirmation from company supervisor and a maintenance manager. The figure is designed for internal use within the company, creating awareness of the factors leading to criticality. This provides a guide that will be able to differentiate between critical parts and non-critical parts, as indicated by the list with the category definitions. Maintenance is included in the fishbone structure, which may seem out of place, as it does not directly translate towards a part being critical to operational conditions. However, it makes sure that parts that are within the first category, planned maintenance parts, are not placed in the critical or non-critical category. There is an argument to be made for the case that these planned maintenance parts can also be critical, this is further explored in section 4.13.2.

Another detail from the fishbone comes from the lead time. A nuance can be created within this category. A threshold may indicate from which lead time a part becomes critical, however a lead time itself does not make a part critical. As an operations manager explained, lead times influence inventory policy, but not directly influence criticality unless the lead time exceeds a certain threshold.

Having a spare part of every capital spare in stock is not a realistic solution for customers for two reasons. It would be very expensive and many vessels operate for their lifetime of 30 years without a failure in most capital spare parts (Beaver specialist, personal communication, 04/05/2022). Financially it does not make sense for customers to invest a huge amount of resources upfront for the unlikely scenario where they will need them early in the vessels lifetime. A simple Return On Investment (ROI) calculation will make the financial division of the customer advise against investing a lot of financial resources upfront. The reason for this is the value of money over time, financial resources invested in capital spares with a very low initial probability of use do not have a direct return on investment. Compare that to an investment of that money in a project that will deliver a return of a certain percentage and it becomes clear why a company does not want large financial resources stuck without a clear return. There is an argument that having capital spares would prevent loss of income due to fast response in case of failure. This is a fair argument and should be the an important part of the service Royal IHC can provide.

Whereas it makes sense for the customer to not buy expensive capital spare upfront, it would be unwise to have uncertainty regarding capital spare availability. These technical considerations will be taken into account when creating the service design.

4.13.2 Criticality

From the fishbone structure in figure 33, an overview can be gained into which parts are critical. After analysing these factors that contribute to a part being critical like function, safety or availability a problem can be seen. This is rooted in the fact that Beaver vessels are build with very few redundancy systems, due to the design philosophy. With little redundancy systems and the fact that the vessel is purely build for performance, almost all parts on the vessel will be critical to some degree. Therefore, a binary choice per part of critical or non-critical is not as useful. In literature, criticality is divided on a scale, not just as a yes or no Molenaers et al. (2012).

For example, a simple bearing that is located somewhere in the system has a critical function, if it fails operation becomes unfeasible because other parts will wear at a significantly higher rate plus the fact that it may lead to unsafe situations. Therefore, under the current system, this part would be classified as critical. Another part on the vessel is the pump casing, it is also critical due to the fact that operation without a functioning pump is impossible. Both these parts are defined as critical, however they are critical due to different reasons and the effects of a failure are very different. The main problem here is the loss of information and the possible issues in communication that are caused by this.

The problem with defining criticality as a yes or no, is that problems can arise in communication internally or externally. As stated before, a part being critical can have several causes; limited suppliers, scarce resources or a high failure rate can be the cause of a part being labelled as critical. Communicating the term critical internally or towards a customer therefore lacks the underpinning of the real issue. Whereas the customer could perceive the term critical as important to the operation, if the reality is that the part is critical due to a lead time of several months, this can cause serious issues when a failure happens and the customer is not prepared for such a delay.

The loss of information is due to the fact that the binary classification as critical or non-critical gives no indication towards the cause of the criticality. Molenaers et al. (2012) concluded that criticality can be calculated by assigning values of importance in different categories. Afterwards these scores are compiled by weighing the categories on importance and a final number can be composed, indicating overall criticality. This research was done in another industry and under different maintenance protocols with a higher quantity of maintenance requests, therefore the numbers that were used should not be taken as accurate for the dredging industry or Beaver vessels. Research from Molenaers et al. (2012) also indicated categories that can be useful to consider in order to classify parts on a criticality scale. In figure 6 some of the possible categories are shown that could be used to indicate criticality in the dredging environment.

Table 6: Categories which contribute to criticality in dredging vessels (Molenaers et al., 2012)

Criticality criteria	*Categories*		
	Vital	*Essential*	*Desirable*
Equipment criticality class	Criticality classes A, B	Criticality classes C, D	Criticality classes E, F
Probability of item failure	≥1/year	≥1/5 year and <1/year	<1/5 year
Replenishment time	>1 month	>2 days and≤1 month	≤2 days
Number of potential suppliers	Only 1 supplier	>1 and ≤3 suppliers	>3 suppliers
Availability of technical specifications	Not available	General specifications available	Detailed specifications available

Where the overall criticality number indicates the relative criticality against other parts, the individual buildup from every criteria provides much information about why the part has this criticality. It can guide the inventory management towards optimal inventory policy, due to the added information.

This system of criticality can be used in combination with the new classification terms. The difference between the critical and non-critical spares can be made by setting a certain threshold from where parts become critical. Or only certain criticality categories have to be analysed in order to make this distinction. This also solves the issue of maintenance parts not being able to be assigned as critical or non-critical. Since each individual part will have its own criticality rating, on which maintenance and inventory policy can be determined.

4.14 Customer survey

Customers are vital to the design of the service. This is due to the fact that the service is only as good as it is perceived by the customers. Therefore, it is valuable to gain insights in the experiences of customers of Royal IHC. A new survey has been send to 15 different Beaver customers. The survey is included in appendix B.

The most recent survey has been taken in February 2022, results are shown in figure 34. The result of this survey are somewhat incomplete. The survey was done by phone and customers only had to indicate performance on categories that were top priority to them. That is the reason why there are a different amount of responses to the questions.

Figure 34: Results from previous customer survey, respondents are anonymized.

It can be seen that the correspondents were positive in their overall rating, which consisted of an average 7.25 out of 10. It is a good mark, but there is still much room for improvement. Product quality is overall scoring very high, with one customer rating it quite low. With a score of 4.3 out of 5, the quality is the highest scoring figure in the questionnaire, underlining the expertise at Royal IHC. The price that Royal IHC charges has been judged with a mark that corresponds to just above average. While, on average, reliability and delivery times are judged as below average. The overall picture of this survey shows that Royal IHC has outstanding products. However, according to the customers, there is room for improvement in almost all parts of the service chain.

In order to gain further insights in the experiences of the customers, a new survey is created. The survey will consist of questions that will both pin the customer on a quantitative judgement and be able to respond in their own words. This gives a good combination of feedback because due to the rating on a Likert scale, general satisfaction can be measured. However, the box underneath the question provides room to note relevant details or other points of feedback.

This extra room for feedback can indicate opportunities previously unknown to Royal IHC. If multiple customers provide the same issues, it can be indicative of a broader problem that should be investigated. This could lead to extra questions in future surveys in order to include this uncovered issue. It is important to note that this survey could and should be tweaked if more information is needed or other questions become redundant. However, if every survey consists of completely new questions, the ability to track customer satisfaction on the same subject over time is gone.

This survey should be send periodically in order to measure service performance over time. Currently the goal of the initial survey is to determine weak points in the current service and measure the willingness of customers towards the extended service design that this project recommends.

4.15 ICT Opportunities

Digitization offers a faster flow of information and communication compared to decades ago. Having the relevant data available in an online medium can increase monitoring and decision making capabilities of managers (Anosike et al., 2021).

At Royal IHC, projects are started to implement this digitization into their dredging products. Specifically, an app called MyIHC is under development. This app would allow vessel owners to access all relevant data of their vessel or fleet. At the moment, operation monitoring is integrated in this app. It allows to view all dashboard information of the vessel on a mobile device. As mentioned, the app is still in development and there are plans to make the app a one-stop-shop for all needs of a vessel. For example, all manuals and safety requirements can be added to this app, but there is also a complete spare part list included. There are also plans to explore the addition of condition based monitoring (CBM), this type of data is currently not yet logged for regular Beaver models. It is an option for the customer to add this type of equipment to their Beaver, however, due to its costly nature many customers do not buy this (Operations monitoring specialist, Personal communication, 09/05/2022).

The digitization department is busy with a roadmap for the MyIHC application. The app would provide multiple people within Royal IHC with valuable information which is needed to perform their work efficiently. It would share production numbers that are valuable to the owner. Spare part availability and location to superintendents, and confirmed spare part prices that help both the maintenance manager from the customer as well as the service department of Royal IHC.

4.16 IoT solutions

The literature has pointed out that a strong base of digitization and IoT technologies can serve as a great platform to build a servitization structure upon. In order to understand the capabilities of Royal IHC regarding servitization, it can be fitting to see how some common IoT features are currently carried out.

Common IoT features include, remote monitoring, location monitoring, live usage data, condition reports, data analytics and data sharing (Naik et al., 2020). As seen in figure 7 created by the author with input from the relevant departments.

Table 7: IoT features and their usage within the current process, plus their potential

IoT feature	Actual usage currently	Potential usage
Remote monitoring	Through E-WON	More relevant maintenance information gathered
Location monitoring	Through E-WON	Reached potential
Live usage data	Through E-WON	Added sensory information beyond dashboard data
Condition reports	On customer request	Generated periodically on available information
Data analytics	On customer request	Generated periodically on available information
Data sharing	Actively through E-WON	High cooperation through data sharing, enabling co-creation

The remote data gathering is being done on a basic level, which can be improved upon if needed. On the Beaver vessels, there is data gathering, but not as extensive as to the point where the maintenance needs of equipment can be predicted. If Royal IHC wants to become more involved with the maintenance of the Beaver vessels, additional sensors on crucial maintenance parts would provide additional information that is useful for both Royal IHC and the customer.

Condition reports are currently not done based on the the information gathered through E-WON, only from physical visits to the vessel. If full usage of IoT solutions would be implemented, there is room for improvement in the data shared with the customers. Added sensors, data analytics and condition based information all have potential value if the information is connected and presented in an usable way.

Track and trace

Track and trace is something usually present in logistical networks and its use within Royal IHC is twofold. First there is the logistical aspect, being able to track logistical progress on parts is a very valuable tool and already in place at Royal IHC. There is also the geographical aspect of track and trace available on the vessels themselves. This gives the owner of the vessel the ability to check where the vessel is operating. It also gives Royal IHC an indication as to the region where the vessels operate in. This indicates that Royal IHC is both knowledgeable of the technology and is also actively using it to gain relevant information to support its digital support system.

RFID

RFID is a technology that could be used in the service process. The advantage is that it combines a lot of information into one scannable code. Parts or packages with RFID would allow for a smooth information transfer, since the information can be easily scanned. Further implementation of this technology might provide Royal IHC with a better information structure in its service chain.

RFID has been used at Royal IHC Beavers before, according to an order manager. It was able to transfer information in an efficient manner, however it was judged redundant. About 80% of part orders are shipped to the customer and put in storage, meaning that there is no immediate use of those parts. The cases where there was an emergency delivery, it was found that the RFID did not add value over the previous process. It was for these reasons that RFID technology has been cut from the process.

Sensors

Sensors have already been discussed, however there is a distinct difference that is unique for Beaver vessels. While more sensors would indeed allow for more accurate insights in the exact state of a vessel and its components, this is not necessarily needed for the business case of the Beaver vessels. Beavers are a very compact and affordable dredging solution, popular with customers in Asia, South America and Africa. Many customers value the affordable solution that Royal IHC offers in their Beaver products. Additional sensors and added service programs would therefore not necessarily make the product more attractive to all customers, merely more expensive. This is a consideration mentioned by many stakeholders and one that requires action at the management level of Royal IHC.

While Royal IHC does have the competences of integrating sensors to get a complete view of the status of a vessel in other, bigger, vessels. It only monitors basic information of its Beaver vessels.

Overall, there is serious room for Royal IHC to improve its digital information structure on the Beaver vessels. RFID and additional sensors have direct benefits in their own area that will support either decision making or analytical processes. However, given the business case of the Beaver product, it is to be seen if these technologies add enough value to justify the increased costs.

4.17 Recommendations for improving current processes

Apart from the improved service design, recommendations are formulated to improve current processes. Goal is to keep customers engaged for longer amounts of time, eventually resulting in more business for IHC compared to initial spare package currently offered. The following list indicates recommendations that will create either a better customer satisfaction or more efficient internal processes. These opportunities are chosen due to the fact that they lay within the competences of Royal IHC and have strong opportunities towards the future. Each recommendation will have an indication towards which stakeholders are included and on what timeline these improvements could be made.

- Keep improving the standard spare part package
- Communicate a clear service program the the customer
- Improvement to internal communication
- Communicate on-site monitoring and assessment of vessel and equipment by Royal IHC maintenance crews
- Create contractual agreements with suppliers with the help of the new-build section of the company
- Provide departments with accurate and relevant data
- Give departments the opportunity to familiarize with the technical side to increase knowledgeably on the high tech nature of the equipment.

4.18 Improvements to the current processes

This section will focus on specific gaps in knowledge or processes that can be improved upon. First, a description of the problem or opportunity will be given. Then, a possible improvement to the current process is introduced.

Keep improving the standard spare part package

The first recommendation contains the intention to keep improving the spare part package. Continuous improvement of service can provide a lasting advantage and the ability to stay relevant. Regarding the standard spare part package, there is room for improvement in a couple of sections.

The first opportunity can be tied towards sales and customer satisfaction. In the sales process, conversations between Royal IHC and the customer will analyse the intended use of the vessel and advise a certain model of Beaver that is best suited for that use. Consideration will be given towards the future and the competition of the client. Variables like the type of soil, the amount of production and future jobs will determine which vessel is most suitable for a customer.

Sales officers indicated that there is a mismatch in this process. How can Royal IHC try to match the customer to the best suitable vessel and then try to sell a standard spare part list that has no regard for soil conditions or production goals? This is where a real improvement of service can be realized, matching the contents of the spare part package to the needs of our customers (Sales manager, personal communication, 30/05/2022).

There are a multitude to variables that will impact the choice of cutter for a dredging vessel. The type of soil is important, operator skill level, and the salinity has to be considered as well. At Royal IHC there are 5 defined types of soil, ranging from sand to rocks. The cutterhead and its teeth have different designs, based on the soil that the customer encounters. For soft soil like sand, a wide teeth is optimal. Whereas a soil that has hard contents like rock, a tooth will have the characteristics of a sharp pick-axe. Another possibility is a muddy soil, which can provide difficulties due to the fact that the soil will stick to the cutterhead and its teeth. These examples show both the high tech engineering that Royal IHC provides and the completely different environments that these dredging vessels might encounter. Which brings back the situation mentioned before, because how can a standard spare part package be aligned to the needs of every customer.

The situation of different equipment for different conditions has to be reflected in the composition and number of spares of the spare part package. The composition part of the spare part package follows from the type of soil the customer expects to encounter. The number of parts are also dependent on the environment that the dredging is done. Wear of the cutterteeth is significantly higher in a hard, rocky soil compared to a softer soil, like sand.

In order to create a spare part package that can be matched to the needs of customers, these different dredging conditions need to be quantified. Initially, historical data can provide an estimation of wear in the specific parts. However, this can be continuously improved upon by updating these numbers from feedback of vessels operating in similar conditions. This way, a customer does not use two year worth of wear parts in the first couple of months of operation, a situation that happens occasionally.

The second improvement to the standard spare part package will be directed towards a clear structure of categorising each part. Especially the conditions under which a part has to be considered critical and what the consequences of that status has.

Communicate a clear service program to the customer

There is no average customer for the Beaver vessels, according to sales officers, every customer has different wishes and needs. However, there are some overlapping traits that customers share. A large part of the customer base of the Beaver vessels consists of both governments and beginning dredging companies. The reality is that they often lack the required knowledge and experience to operate the vessel optimally. This lack of experience is also seen in the sales process, where sales staff will try to match the customer with a Beaver vessel that fits their needs and gives them a favorable position against competitors (Sales manager). While this sentiment of helping the customer get a suitable vessel is shared, the technical knowledge of the sales team is not on the level of Royal IHC's dredging advisory services, also known as DAS. An operations manager explained that DAS would do extensive technical research on soil condition and operational parameters and create an advice based on those results. In his experience, those reports are more reliable than the, good willed, insights of sales staff. Which makes sense, since DAS is specialized in advising dredgers to optimally use their equipment.

This results in the recommendation to actively involve DAS in the sales process. It would allow Royal IHC to create a better match for the customer with a technical underpinning. This also follows the philosophy of the restructured service package.

Improvement to internal communication

The internal communication is an area that shows potential for improvement. As mentioned in section 4.3, the communication between different departments is lacking. In the service process this can be seen in multiple places, most notably in communication between local offices and the main office in Kinderdijk. According to a service specialist, there is not a lot of information coming back to the Royal IHC headquarters in Kinderdijk from the foreign offices. Specifically, this is regarding service reports that should be written and communicated after a service engineer visited a certain vessel. At the moment, not all of these reports are fully made or communicated. This leaves the office in the Netherlands with little information about the status of the visited vessels.

According to a satellite office manager, in the past, this issue was not as visible due to other factors. The local offices would know the status of most of the customers vessels. Even without the official order, spares would be bought as inventory since from the visit it was apparent that those parts would be needed in the near future. However, due to Royal IHC not being in a great spot financially, most budget for buying inventory without an order has disappeared. Inexpensive parts will still be bought for inventory, but bigger parts like a pump casing are out of the question. meaning that customers can expect significantly longer lead times for spare parts.

Combine that with the fact that most reports from visits do not get to the main office in the Netherlands and the problem becomes clear. Without the general information that may indicate a need for specific parts, it is harder to keep inventory efficient, yet relevant.

Create contractual agreements with suppliers with the help of the new-build section of the company

Currently, the building of Beaver vessels and the service of them are two different processes, handled by different departments. The new-build section assembles and outfits the Beaver models and builds them to stock. The service department is responsible for delivering the initial spare part package and any service requests that appear afterwards. This creates a division between the two processes, where on the one side new-build makes sure that they equip the Beaver vessels with relevant parts. On the other side there is the service department that has to make sure that all of those parts can be acquired and delivered to customers afterwards.

A problem that appears is that the service department is very dependent on the availability of the parts that new-build originally installed on the vessels. However, historically, new-build has not made very tight contractual agreements with suppliers that cover availability of parts for the lifetime of the vessels. This is the base of the recommendation, because obsolete parts or changing availability creates challenges for Royal IHC services and, by extension, the customers.

The new-build department of Royal IHC would be in a better position to negotiate these contracts due to their stronger position towards suppliers. Where the service department will occasionally buy spare parts from suppliers, new-build will buy the parts of a whole range of Beavers. This gives them a better position to negotiate a contract that benefits the service department after the vessel is delivered.

Provide departments with accurate and relevant data

Another remnant of the business unit structure that was the core of Royal IHC for a long time, is found in the sharing of data. In different parts of the service process, relevant data is missing or hard to acquire. Let's examine two examples of this phenomena.

The first issue is found within the sales department, where sales officers do not have easy access to relevant data. Beaver vessels have been sold with standard spare part packages for years. However, over the years some parts or quantities have changed due to a change in supplier, or a change in maintenance approach. Once the vessel is sold, the customer receives the spare part list that is accurate at that moment. Whenever said customer comes back some time afterwards to order some extra spares from that list it presents a problem for the sales department. This problem is caused by the fact that sales only has easy access to the current spare part package list, thereby having no reference to the list as it was whenever it was sold.

At the moment this problem is solved by extra lines of communication with the service department in Kinderdijk to get the correct information, resulting in unnecessary time loss for both Royal IHC and the customer. However, this problem could also be solved if sales would have access to the data themselves.

Give departments the opportunity to familiarize with the technical side to increase knowledgeably on the high tech nature of the equipment

Although Beavers are among the smallest vessels that Royal IHC produces, they are high tech products. Many departments within the service chain are not completely familiar with the technical side of the vessel. Both sales and back office personnel have mentioned that having better technical knowledge on the vessel and its parts could provide useful for their processes.

4.19 Sub-conclusion

After careful analysis of the current processes and the infrastructure in place, the following conclusions can be taken. First of all, regarding the sales process. There are opportunities in the sales process to make the service program smoother. More service options can be included in the initial purchase, giving both parties more certainty about the relationship going forward. The role of DAS has been analysed and would certainly be interesting to include in the service design.

The vessel commissioning is good at the moment. Every customer agrees to take the initial training and in practice it works efficiently. There are still options to increase efficiency afterwards with additional training. However, during the commissioning of the vessel the initial training is more than sufficient for the customers.

Planned maintenance systems offer a great opportunity for an improvement to the service design. Since the planned maintenance schedule is known and planned when the vessel is delivered. Royal IHC might be able to capitalize on the opportunity to provide and install these parts at those aforementioned scheduled maintenance times.

Service contracts have their use cases, however there are too many limitations as of yet to implement this as a key part of the new service design.

Operational profiles offer much potential for the future. Predictive maintenance and increased availability are both aspects that can be the result of extensive knowledge of a vessels operational profile. Since Beaver vessels are standard and the installed base is substantial, there should be enough data to create general operational profiles. The limitations are the geographical differences, operator skill level, and different project types. All of which make comparing the same vessel in different circumstances difficult.

The stakeholder analysis did an overview of the most important stakeholders and their goals on the project. This resulted in three groups of stakeholders that had both a big interest and impact on the project. For that reason, interactions and communication with those stakeholders were more important. An engagement plan was formulated in order to make sure that all major stakeholders would agree to cooperate.

A Hardware breakdown structure showed the differences between part categories. It also indicated what aspects create those differences, like lead time, price, and the number of suppliers. These factors, combined with customer wishes offer opportunities for customization in the initial spare part package.

The current classification system for parts has been analysed and a new system has been proposed. This has been done in a multidisciplinary group to create a clear internal and external messaging within the naming of parts.

Results of the last customer survey are shared, with the general conclusion that the quality of products is very high for Royal IHC. However, service elements like delivery time or reliability are rated too low. Resulting in the knowledge of what part of the service process can be improved upon. A new questionnaire is send to 15 different customers in order to receive feedback on both the satisfaction currently, as well as finding out if the new design elements are something the customers would agree with.

Different cutting edge IoT technologies that would support servitization initiatives are already present within Royal IHC. However, due to the business case for Beavers, the integration on this specific product, in general, is still low. The added information and actions that follow from it should therefore be able to justify the increased product or service cost.

Lastly, recommendations from the analysis are shared. After a deep dive in all the processes in the service chain and the people that are involved, some low hanging fruits are identified. These low hanging fruits are improvements that can be done relatively easy without much investment of resources, while delivering improvements compared to the current process.

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5 Requirements for the new service design

As indicated by figure 35, this chapter will define the design requirements. The research component of this thesis project has been concluded in chapter 3 and 4 respectively. With both those research chapters leading to important information that can be used to construct the requirements for the service design. After the requirements have been established, the service design can be created in chapter 6.

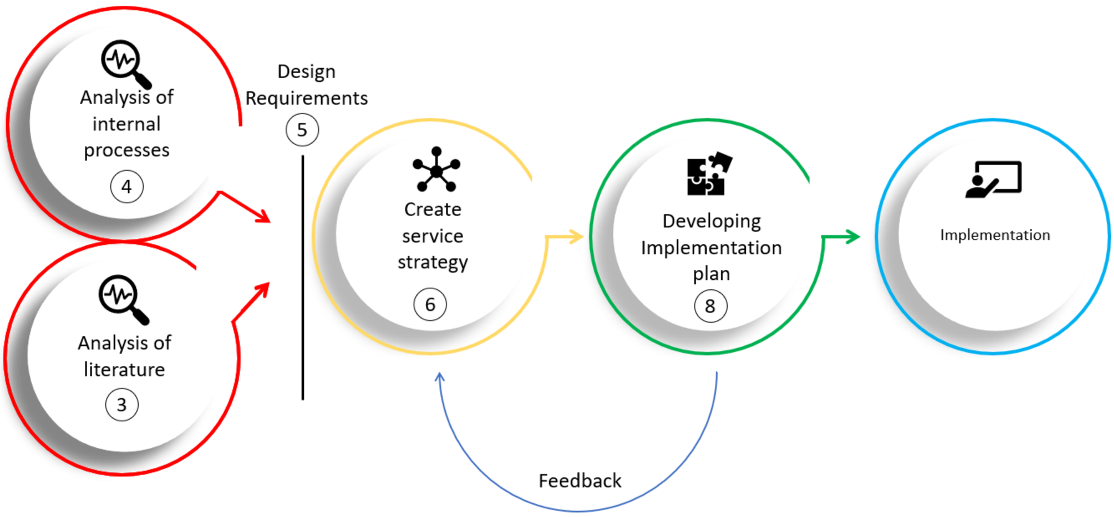

Figure 35: Design process, with chapter indications included, inspired by (Tschimmel, 2012) and (Li et al., 2020)

In the design process it is important to keep the goal of Royal IHC in mind. As a whole, Royal IHC strives to become a trustworthy partner that plays a leading role in making the maritime industry utilise assets more efficiently and sustainable. Whereas the specific goal of Royal IHC Services is to make the other parts of Royal IHC a trustworthy partner.

This chapter will show an overview of all requirements, following the MoSCoW method (Wiegers, 2013). The MoSCoW method is described as a best practice in software engineering due to the ability to quickly identify which requirements are critical or add the most return on investment. This method divides the requirements in the following four categories; Must haves, Should haves, Could haves, and Won't haves. Requirements indicated as must haves need to be present in the eventual design in order to successfully complete the project. Should haves are a very good addition to the final product. However, without them the end product or service is still usable. Could haves are requirements that will be handled if there is enough time, but do not have as much of an impact as should haves. Lastly, Won't haves are the category of requirements that will not be included in the final service design. This is indicative for future projects due to the potential that these ideas have. However, due to the circumstances, these requirements are not included in the current service design.

Table 8 shows the requirements in one place. It indicates the classification under the MoSCoW method, as explained above. There is an indication if it involves a technical or functional requirement. The origin of the requirement is explained, as is the support from either company experts or literature on the importance or relevance of the requirement.

MoSCoW	Technical of functional	Requirements	Origin of requirement	Referrenced	Expert statements
Must have	Technical	The parts on the standard spare part list should be classified in such a way that communication to the customer and communication internally is clear	Analysis of internal processes	Managers/supervisor/Sales officer	"Having different terms for the same parts is confusing to both employees as wel as customers."
Should have	Technical	Create customizability within the standard spare part package to account for environmental operating conditions	Analysis of internal processes	Maintenance manager/Supervisor	"It is not logical to sell a tailor made dredging solution to a customer and then use a standard spare part packahe withpout regard for circumstances."
Must have	Functional	The new service should have different tiers of service, in order to fill the need of each customer	Company requirement	Supervisor	
Must have	Technical	The improvements should come from experience and knowledge already within Royal IHC	Analysis of internal processes	Supervisor/DAS	"Due to the financial situation of the company, improvements from existing processes are preferred over heavy investment of resources."
Must have	Functional	The new service design should retain customers for future service requests	Literature and company requirement	Supervisor/literature (Ranaweera & Prabhm (2003)	
Must have	Functional	The new service should increase satisfaction for all customers	Company requirement	Supervisor/Author/DAS	"Our customer are very different and range from megacompanies to beginning dredgers. It is important to find a solution that works for all out customers and not just the extremes."
Should have	Functional	A process should be in place that monitors customer satisfaction and feedback in order to improve the service	Analysis of internal processes	Author/Supervisor	"A feedback loop would allow for continous improvement of the service design over time"
Must have	Functional	Transition from a passive, reactive service, towards a proactive service design	Literature and internal conversations	Author/DAS/Literature (Lenka et al. (2017))	"Taking a more active role in the support of our customer will eventually lead to increased customer retention, if the service quality stays high"
Must have	Functional	The new service design should have a more complete operation monitoring in place for customer that desire it	Literature and Analysis of internal processes	Author/Supervisor/Literature (Naik et al. (2020)), (Martin-Pena et al. (2020))	
Should have	Technical	The service design should be able to turn a profit	Analysis of internal processes	Supervisor/Author	The PMG has the final word on pricing, we essentially just provide a suggestion on content and pricing of the service.
Won't have	Functional	Performance based contracts as a standard part of the service	Analysis of internal processes	Maintenance manager/Author	
Won't have	Technical	Full predictive maintenance integration in the service design	Analysis of internal processes	Maintenance manager/Author	
Won't have	Functional	Full service support for existing vessels	Project limitation due to scoping	Author	

Table 8: Requirements, including the type, origin and those whom confirmed them

Requirements from sub-research questions

As stated in chapter 2, a couple of research questions guided the project through the most important information available relevant to the service process. The analysis of these processes resulted in both a clear overview of current practices and insights into areas that could be improved upon. A couple of these insights will be elaborated upon in this chapter, these insights will act as requirements for the improved service design.

5.1 Technical requirements

One of the requirements that follow from the analysis, is the technical one. After analysis of the internal processes and technical underpinning of the spare part list, a new categorization and definitions list have been proposed. With this new categorization, Royal IHC is able to define parts into different classifications to define their criticality. The new model has underpinning in state of the art literature instead of the old process that was largely based on a combination of experience and intuition. Experience and intuition could function as a guiding principle for deciding classification of parts, however the main problem was that communication and documentation appeared to be missing. As people in the organization indicated; "Having different terms for the same parts is confusing to both employees as well as customers". Leading to confusing communication and the misuse of the term critical part. This new classification of parts and their criticality will be used as a requirement for the new service design. The reason is that it would provide clear definitions that can be used company wide to assign spare parts into their distinctive categories.

Requirement 1: ***The parts on the standard spare part list should be classified in such a way that communication to the customer and communication internally is clear.***

Another technical requirement comes from the fact that the current spare part list functions as a one size fits all, when in reality this is not always the case. Management from the maintenance side indicated that there certainly is room for improvement on the spare part list. Currently, the standard spare part list has very little room for customization unless the customer specifically asks, and is willing to pay, for it. If Royal IHC were to sell a Beaver 50 vessel to a company dredging in Indonesia or Brazil, currently they would have the same spare part package. However, the environmental factors are a huge part of the actual wear of the vessel and its components. Salinity or soil conditions will differ everywhere and these conditions together with the skill of the operator will mainly determine the rate of wear. This difference of wear will impact certain parts that directly interact with the dredging operation, such as cutter-teeth, impeller, and the pipe where the soil is transported through. This requirement would at the moment be classified as a nice to have, since the knowledge that is needed is not at that level yet. However, it would be wise to start documenting and monitoring information regarding this wear in order to improve the package in the future to account for this. As a sales officer mentioned; "It is not logical to sell a tailor made dredging solution to a customer and then use a standard spare part package without any regard for circumstances. This requirement has also been a focus point in meetings with a maintenance manager, as well as the company supervisor and a sales employee. This creates the next requirement that will be noted as a nice to have;

Requirement 2: ***Create customizability within the standard spare part package to account for environmental operating conditions.***

5.2 Company requirements

Company requirements come from additional insights stemming from the research questions or directives from Royal IHC. In this project, the goal for Royal IHC was to create a layered service for customers to choose from. This structure should follow a bronze, silver, and gold tier system, where each tier would gain additional service benefits for a fair compensation. The choice that has been made to follow a tiered system consisting of three tiers seems arbitrary, however it does serve a purpose. Three options has a lot of ability to push customers in a tier that is not the lowest one. If many recurring services are placed in either the middle, top or both tiers, that will effectively increase customer retention of the Royal IHC services. This will be harder to do if the tiered system is extended with more intermediate choices. This setup for the service design has originated from and is confirmed by the company supervisor. This results in the following requirement;

Requirement 3: ***The new service should propose three different tiers of service, in order to fill the need of each customer.***

Another wish from Royal IHC is that the improved service should play on the strengths of Royal IHC. In this case, the strengths of Royal IHC are their experience, intimate knowledge of the product and sector, and the connections within the dredging sector. Ideally the strength of Royal IHC plays perfectly into the service a customer needs. Due to the financial condition that Royal IHC is in, it would be ideal if improvements are made without large investments. This is resonated by an advisor from DAS; "Due to the financial situation of the company, improvement from existing processes are preferred over heavy investment of resources." It would be advantageous if the improvements stemmed from knowledge already within the company.

Requirement 4: ***The improvements should come from experience and knowledge already within Royal IHC.***

5.3 Customer requirements

This project has started due to the fact that Royal IHC management noticed that customers would not return to Royal IHC for many of their spare parts. A big requirement for the service therefore is to make sure that the retention of customers is higher than it is now. Trust and satisfaction are important drivers when it comes to customer retention (Ranaweera & Prabhu, 2003). For this reason, the new design should aim to improve internal processes and improve customer satisfaction. The improved internal processes would allow for more competitive pricing or faster response times, whereas the improved customer satisfaction would encourage customers to return to Royal IHC in the future. This results in the following requirement;

Requirement 5: ***The new service design should retain customers for future service requests.***

The proposed service has to make sense for the customers, this means that it has to translate into a solution that fits within a reasonable budget and that the service covers the customer needs. An important note is that Beavers are sold to different type of customers, from large dredging companies with much experience, to starting dredgers in remote areas (Beavers installed base specialist, personal communication). The service has to be offered in a way where both these extremes on the scale, but also the customers somewhere in between are satisfied. The degree to which each of these customers are satisfied can change, however the overall satisfaction should increase for all. This sentiment has been put forward by a Beaver specialist within Royal IHC; "Our customers are very different and range from megacompanies to dredging beginners. It is important to find a solution that works for all our customers and not just the extremes". This requirement has been confirmed from both management as well as the sales department. Therefore the following requirement is noted;

Requirement 6: ***The new service should increase satisfaction for all customers.***

In order to keep improving the service towards customers, feedback can play a big role. The service can be improved if the perception on the service of the customer is known. As customers may be unaware of internal processes, their perception of the performance of the service is also unknown. A questionnaire will be prepared for existing customers in order to create a feedback system to monitor the performance of the service from the customers viewpoint. Currently such a feedback loop is not in place as a standard process, however due to the added value that this feedback can have it would be nice to have. This recommendation is based on the authors experiences within the company and has been confirmed by the company supervisor. Feedback from customers on a more regular base gives feedback on the level of products and services that Royal IHC has. Getting regular feedback, with the addition of being able to add new relevant questions to such a feedback system can really improve the design over time. This requirement has been marked as a should have, following the MoSCoW method. The reasoning for this is that this feedback loop is not an element that is critical to designing a functional service, however it would allow for the service design to become more refined over time. It give the following recommendation;

Requirement 7: ***A process should be in place that monitors customer satisfaction and feedback in order to improve the service.***

Currently, the service provided to the customer is reactive, only initiated after a request from the customer. This is a missed opportunity because a customer might not be aware of added value opportunities that Royal IHC can offer. It also means that processes will always be started after requests from customers, meaning that in general, these processes take longer. If the new service design would take a more proactive approach towards the service, anticipating on the needs of customers would become easier, since Royal IHC would already be proactively engaged with them. This switch from reactive to proactive can offer customers value in places where they might not have expected it themselves. From operational efficiency to maintenance, Royal IHC can add value by being more proactive towards their customers. This is resonated by (Lenka et al., 2017), who claims that this proactive relationship with the customer can unlock important co-creation effects. This requirement has been developed during brainstorming sessions with Dredging Advisory Services. It leads to the following requirement;

Requirement 8: ***Transition from a passive, reactive service, towards a proactive service design.***

The last requirement is a functional one. It is regarding providing customers and Royal IHC with additional information on the Beaver vessel. A more structured way to communicate and share the status of a vessel would allow for such practices. The literature supports the digitization of information in servitization environments. For example, (Martín-Pena et al., 2020) indicated that increased digitization of communication and monitoring can lead to improved servitization practices. This is underlined by (Naik et al., 2020), by highlighting the affordances related to servitization practices. A strong digitized framework is required in order to add value to the customers practices.

Currently Royal IHC already has the processes in place that execute different types of monitoring. Both operation monitoring and vessel visits are being done at the moment. However, at the moment this information is barely exchanged or acted upon. By having a structure that connects these practices, better information on vessels can be gathered and more profound analysis can be done. This requirement is confirmed by the company supervisor and is stated as follow;

Requirement 9: ***The new service design should have a more complete operation monitoring in place for customer that want it.***

From the company, there is no strict requirement on the investment required for this initiative. As a service manager explained; in general, initiatives in the service department should be aimed towards generating profits. However, there is a fine distinction in this case due to how the company is structured. Right now, Royal IHC Services generates a spare part list for every new Beaver vessel that is sold, however, this is only a proposal that does not need to be followed completely by the product market group (PMG). The PMG will determine the final composition of parts and the pricing for the customer. The PMG has the authority to either increase or decrease the price for the customer on their own. A variable that is included in this reasoning is the relation with a customer and possible future commitments for a far bigger vessel. One might understand that a package of spare parts is only a little investment compared to an order for a custom build vessel. As a service manager explained; "The PMG has the final word on pricing, we essentially just provide a suggestion on content and pricing of the service."

This dynamic of the PMG having the final word on pricing also means that there is no hard requirement on the ability of this initiative to generate money. However, being able to realise net profits would create a far bigger incentive to actually implement the service design. Due to these circumstances, there is no hard requirement about being able to generate a net positive cash flow in the final design. However, it would be nice to have since it would increase the chance of implementation. This translates in the following requirement, classified as a should have, using the MoSCoW method.

Requirement 10: ***The service design should be able to turn a profit.***

5.4 Requirements that are not included

The last category of requirements from the MoSCoW method are the 'won't haves'. This project identifies three specific requirements in that category. These requirements are not used to design the service model, however due to their future potential they are mentioned. This way, it is easier for future iterations or initiatives to evaluate if these requirements are at a point where implementation would be feasible.

The first requirement that will not be included in the final design are the performance based contracts. While these types of agreements would offer a lot of potential in the future according to a senior maintenance manager, the resources to implement such a service in the near future are not available. More testing, knowledge and process integration is needed to fully capitalize on this opportunity. While the author would agree on the potential of this service-based approach, the company is currently not positioned to implement this in its service package as a standard for every new vessel. Therefore, this requirement will be labelled a won't have.

Requirement 11: ***Performance based contracts as a standard part of the service.***

The next requirement pertains to the predictive maintenance integration on Beaver vessels. In order to capitalize on the additional information predictive maintenance can offer, Beaver vessels will have to be redesigned or retrofitted. Before this action should be taken, maintenance should have clear expectations of the information that is required. As the analysis of internal processes indicated, only basic information is currently gathered. In order to fully use the potential of predictive maintenance, a clear overview of actual outputs is needed (Killeen et al., 2019). Due to this not being the case, and the aforementioned lack of resources, this requirement will not be included in the design that this project will create.

Requirement 12: ***Full predictive maintenance integration in the service design.***

As mentioned in chapter 2.8, the service will be designed for new Beaver vessels. While the author understands that there is a lot of revenue to be gained from the substantial installed base, there are many factors that will make full support of vessels in the installed base difficult. Due to unknown circumstances on board, lack of sensors or equipment, obsolete parts still in operation, and other aspects, it will be difficult to start a service that can account for every details in the installed base. Therefore the decision is made to start this service from a point where all information in available to Royal IHC. Yes, there is a lot of potential to extend the service design to include the installed base in the future, it should first be tested on new vessels. This translates in the following requirement that is classified as a won't have.

Requirement 13: ***Full service support for existing vessels.***

These thirteen requirements will act as guides in which the final design is created. Of the thirteen requirements, seven are must haves. These requirements can be seen as strict rules or effects that the new design has to adhere to. three of the requirements are categorized as should haves, this means that it would be beneficial to include them, but it is not as important as the others, as the service can exist without them. Lastly, there are three requirements that are classified as won't haves. These requirements do show promise towards the future, however implementation is not feasible at the moment.

5.5 Sub-conclusion

This chapter set out to define the requirements that would determine what the service design has to be based around. There are a mix of technical and functional requirements mentioned. The technical requirements are limitations and opportunities that happen behind the scenes, but can also be seen as the foundation on which the design is based. While the functional requirements would indicate a specific function that the design needs to have.

The requirements will return in section 6.4, where the design is compared to the requirements to verify their inclusion.

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6 Creating the new service design

In this chapter, the improved service design will be explored, as can be seen in figure 36. The requirements created in chapter 5 will function as guidelines that lead to a service design. A service design that emphasises the strengths of Royal IHC in order to create value for customers. There is also a methodology included that will codify spare parts, their function and the way they interact with maintenance. This should make it easier to have an accurate list that can easily be adapted to certain wishes or requirements from customers.

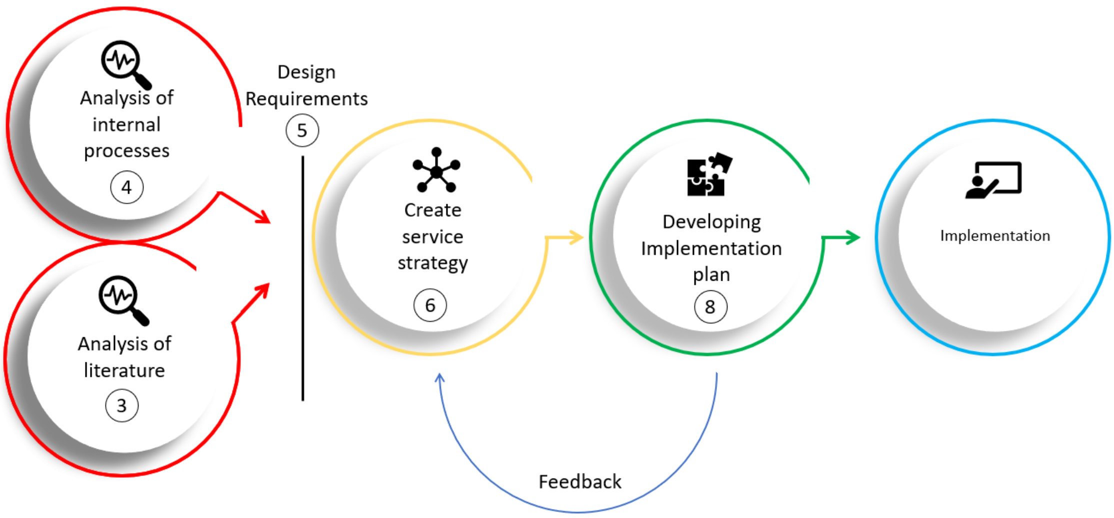

Figure 36: Design process, with chapter indications included, inspired by (Tschimmel, 2012) and (Li et al., 2020)

6.1 Multi-tiered strategical approach

The idea is that the restructured service design adheres to a customer based approach. The most important factors are that the improvements should come from strengths within Royal IHC, customer satisfaction, and improvements on current internal processes. The general idea is that an improved relation with customers would translate into a better working relation in order to keep customers engaged with Royal IHC for a longer time. This is done by making sure that customers understand from the beginning that Royal IHC has valuable experience that can help customers in many parts of their operations. Maintenance, operational efficiency, and training are all part of competencies that Royal IHC has and many new customers lack.

An important part of creating a strong relationship with the customer would be recurring positive interaction (DAS consultant, personal communication). If the amount of interaction can be increased in a way where every interaction will add value or convenience for clients, this would increase overall satisfaction.

Another more major change is the switch from reactive towards proactive. Currently most processes are only initiated on request of a customer. The advantage is that Royal IHC will only put resources in orders that are confirmed and effort can be put towards improving internal processes. However, this project will try and add some proactive elements in the mix. Being proactive in certain parts of the service program has its benefits. It can help customers with issues that Royal IHC knows that they will experience and due to the proactive nature, solutions can be provided earlier. It can also be applied to maintenance packages, Certain parts have to be replaced for each period of time or number of production. At Royal IHC the production hours and production is being monitored, which means that those spare parts could be shipped proactively. A proactive stance from Royal IHC can provide service in a more timely manner, while also giving Royal IHC more time to prepare said service due to the fact that this proactive maintenance can be monitored and therefore planned. Being able to carry out maintenance on a timeline can be managed more easily compared to reacting to every single order that is coming from customers.

As will be shown in this chapter, the multi-tiered strategical approach is able to fit these goals in the service design.

Servitization level

The three levels of servitization have already been pointed out in chapter 1. Due to the capabilities and financial tools of the organization at the moment, the switch towards the advanced servitization model will be excluded. This is due to the fact that this step would take considerate resources in all departments that are connected to the service process. Transitioning towards an outcome based product would require changes in approach, handling, and execution of all services related to the Beaver services. While this would be a good opportunity to investigate further, at the moment it would not make sense. The basic servitization model is comparable with the situation at the moment. A product, the Beaver vessel, is sold to the customer and repair and part requests are available to the customer. However, continuous services are not contractually agreed upon. Customers can contact Royal IHC in case of a request or consultation, however this is currently underused in the eyes of service managers.

The intermediate servitization level would be interesting for the company in its current state. It can make use of IoT solutions like remote monitoring and can also provide economies of scale advantages for Royal IHC by providing continuous spare part packages to many customers on a regular interval. Other services that can be included are training, consultancy and inventory control. The big change with the current situation would be the continuous support to the product with a proactive stance from Royal IHC.

6.2 Service design

There needs to be a clear picture towards the customer as to what Royal IHC offers, what products and services are included in the package and how is it organized. These services play into the strengths of Royal IHC and provide added value to customers. In figure 37, an overview is given of the proposed service tiers. In the future, the dredging industry should know that Royal IHC offers quality support for their Beaver vessel depending on the needs of each customer. By having standard operating methods and processes, customer know what to expect and can rely on the expertise from Royal IHC.

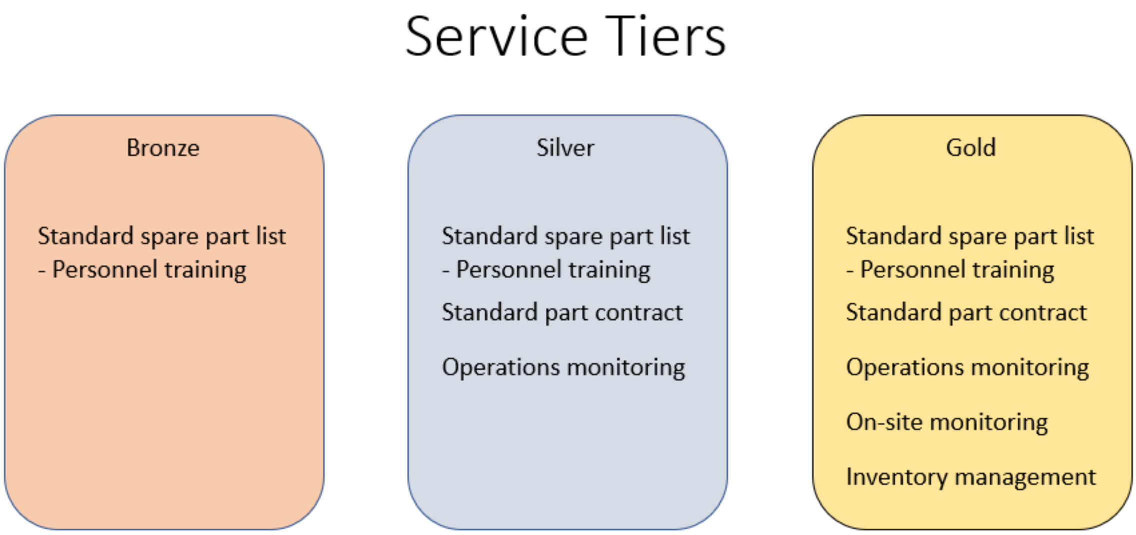

Figure 37: Proposed multi-tiered service design.

6.2.1 Methodology for creating the different tiers

From the requirements, the tiered system was communicated as a must have. It also makes sense due to the fact that the range of customers is quite large. Different cultures, experiences and use cases all require different interactions and having multiple service tiers give customers the freedom to choose their level of cooperation with Royal IHC, instead of being forced in a one-size-fits-all solution.

The next big task is to fill the packages in such a way that it creates both a solution for people that want little support as well as customers that want the full service package. In order to satisfy customers that operate independently and prefer to setup their own supply chain, the bronze tier has been inspired by the service as it is currently. The vessel is supplied and commissioned while the personnel is trained to operate it. A standard spare part package is included to keep the vessel operational for at least a year. Alternatively, the gold tier is designed to hold the complete range of available service from Royal IHC for Beaver vessels.

The next challenge was to design the silver service package. The goal of the silver package is to exist and push people towards the gold package. This is a common strategy in marketing where the middle option can be used to make either bronze or gold seem more attractive. This decoy phenomenon changes the customers preference between two products when presented by an asymmetrically dominated third option (Huber et al., 1982). Practically, with the bronze tier being quite bare-bones and having no predetermined support after the initial delivery it is cheaper compared to gold. However, by pricing silver closer to gold, this creates the illusion of gold being a better deal, due to silver being relatively overpriced. This effect can be amplified by putting a big and important service solution in the gold tier as well, namely the inventory management.

This marketing technique is no guarantee since there are customers that have strong predetermined opinions on what they need and what they do not need. However, it might influence the customers that are on the fence about the level of cooperation.

Bronze tier package

The bronze package is very comparable with the existing service, it delivers an initial spare part package which can sustain the customer for a while before additional service is needed. It also has the training included that Royal IHC provides. The training itself is not mandatory. however, as the manager of the training activities confirmed, the operational training is done by all customers. It is therefore included in the entry level service tier.

Silver tier package

The silver tier has the same elements that the bronze tier has, plus some extra services provided by Royal IHC. One of these services is the standard part contract. It will allow customers to receive maintenance parts that need to replaced in a predictable way, either due to operational hours or production volume. This way, the customer does not need to create their own supply chain of all these individual parts and can rely on Royal IHC to ship them when this planned maintenance is needed. Operation monitoring is an added service that is needed for Royal IHC in order to be able to predict these maintenance needs of the standard maintenance parts. However, it will also provide valuable information to the owner of the vessel, as discussed in section 4.8.2. On a general level, the added benefit of the silver tier compared to bronze is the constant supply of required maintenance parts that the vessel will need to stay operational.

Gold tier package

The gold tier has the same elements that the silver tier, and therefore the bronze tier, has. However it will go one step further in creating a partnership with the customer. Where the silver tier supplies the standard maintenance parts, like filters or worn rubbers, the gold package will also work with the customer in creating a supply chain for their wear parts. The difficulty of wear parts is that due to many factors, the actual wear can be difficult to predict, combine this with long lead times and the fact that these parts can be expensive and the problem becomes visible. It can be hard for the customer to understand when to replace certain parts, especially when lead times may require very advanced notice. The gold tier will combine the best maintenance package that Royal IHC can offer. Increased interaction with the customer, using the Royal IHC experience and expertise in order to predict and plan wear part usage. This gold package will aim to lessen the maintenance load on the customer by working in an proactive way in order to keep the vessel operational.

On-site monitoring and inventory management are the two term that add the ability to better understand the wear part needs of a customer and have spares available when needed. On-site monitoring will add information that can slip past the operation monitoring systems. Both the digital monitoring systems and regular on-site inspections, provide the data for Royal IHC and the customer in order to create a maintenance plan that works for the customer. Inventory management is largely an internal Royal IHC process, however in this context it indicates that important wear parts will be available whenever needed by gold tier customers. This is a huge advantage to customer, since lead times of certain parts can take up to months, these are usually Royal IHC, or its subsidiaries, specific parts. Pump casings or impellers are examples of these parts with lead times that can take multiple months.

6.3 Service process

The internal processes of Royal IHC should change in order to anticipate the change of service that is offered to the customer. The proposed service process is shown in figure 39. I order to accurately notice the difference with the current service process, figure 38 reflects the current situation. This figure has already been shown in section 4, but will be shown again for easier comparison between the two service designs.

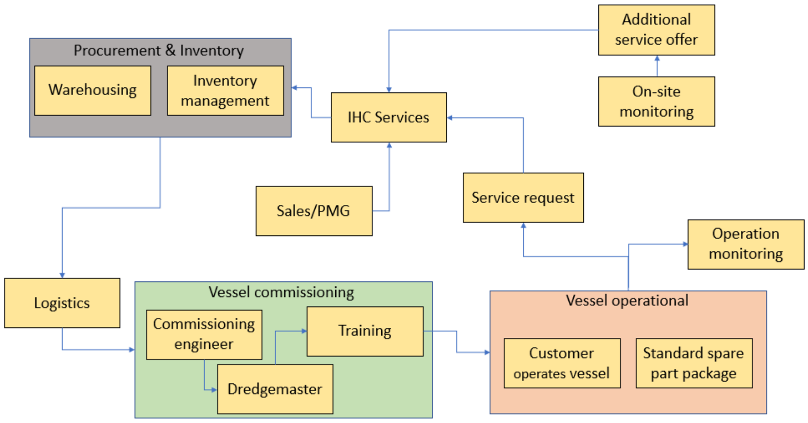

Figure 38: Existing service process.

There are a couple of processes that have added responsibilities due to the extension of service that will be provided to customers. Other processes will have to be extended in order to make internal processes more efficient or transparent. In figure 39, the proposed service design is shown. It differs to the existing design on a couple of points, these changes will be explained in this section. The process overview has been created by the author and confirmed by company supervisor.

The blue arrows indicate the flow of processes. The arrows indicate which way the service flows. Blue lines are processes that are being initiated or executed, Red dotted lines are communication lines. Specifically, the red dotted lines indicated in this process are the added lines of communication that would support the service process.

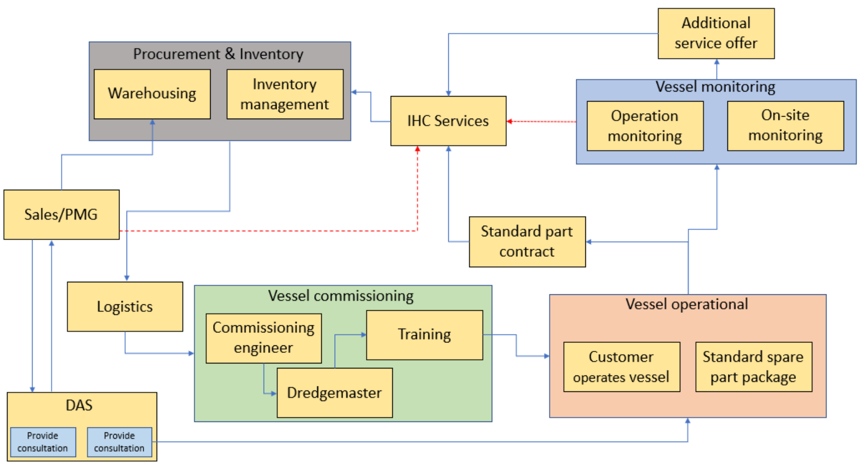

Figure 39: Proposed service process.

6.3.1 Dredging Advisory Services

First of all, Dredging Advisory Services (DAS) is a consultancy service of Royal IHC that can provide technical feedback on dredging operations. Information from operation monitoring in combination with analysing data being taken on board of the vessel can be translated to specific advice in order to increase efficiency. At the moment, DAS is consulted sometimes in the sales process. Most their activities in this phase will be analysing soil conditions and making sure that the right cutterhead is chosen in order to perform efficiently. Their findings will be reported to the customer and labeled as recommendation, meaning that the customer is always free to choose another option, However considering the conditions, the advise from DAS will be most beneficial for the customer, and is accepted most of the times due to that reason. It also happens that the customer orders a complete analysis of a certain project by DAS in the purchase phase. This is extra work and DAS will analyse the specific project and its details in order to advise the customer.

DAS can also provide consultancy during the operational phase of the vessel. Often, an engineer will go to the vessel in order to collect and measure specific vessel data. With this data and the experience of the engineer on board, extra training can be provided in order to improve efficiency.

In the new service design, DAS will have some increased responsibilities and provide value to customers. DAS is currently not involved in every sales process of Beaver vessels. A DAS consultant explained that some sort of questionnaire can be created that will provide DAS with the information needed to provide an advice on aspects like cutterheads. This would increase the role of DAS in the sales process, without increasing their workload substantially. An extensive analysis can still be provided if the customer requests it.

During the operational phase, DAS can provide operational advice to customers. In the new process, DAS will be involved more closely with customers. The main reason is the fact that DAS has experience and technical data that will help any type of customer reach a better efficiency of their vessel. This is valuable because it is information that is already within Royal IHC and it is information that most customers appreciate. Involving DAS can be agreed upon in the initial contract, due to advantages that will be explained in section 6.3.4.

6.3.2 Vessel monitoring

Whereas operation monitoring and on-site monitoring are being done already, much of this information is not used to its potential. Operation monitoring will collect operational data which can be processed. However, as state of the art literature noted, without event data, it can be hard to accurately process certain data into accurate maintenance or operational information (Jardine et al., 2006). In this context, event data means that the vessel encountered a certain problem that cannot solely be explained by the monitoring data, however if the event is known the data can be used to explain those circumstances. For example, the data might indicate a loss of production for a certain time period. However, there can me many reasons for this production loss. If it is known that the loss of production was caused by an event such as changing weather conditions or changing of personnel, the data can be reinterpreted to check which data markers account for this event. Then future data can check for these markers and conclusions that were previously not possible to make are instead possible.

On-site monitoring is also a process that is executed for customers already, service engineers will visit Beavers from customers and provide feedback or maintenance recommendations. It used to be that for every visit, a report would be made with observations and the current state of the asset. However, according to a regional office manager, currently these reports are not being made every time and when they are made they often do not reach everybody that would benefit from this information. This information is lost, whereas it has the potential to inform the maintenance section of event information and observations that could explain certain data from their monitoring systems.

The new design would group the two processes and couple them in order to make sure that the information is shared to the relevant parties. The relevant parties in this process would be the satellite offices, service maintenance and the account manager of the vessels. A manager from service maintenance has indicated that there is more data stored than currently displayed through E-WON. However, this data cannot be used at the moment due to uncertainties about the relevance or causality. If this data can be combined with actual on-site observations and event information, there are possibilities to further increase the performance and relevance of the monitoring systems. Currently there is a need to perform on-site visitation in order to get a clear picture of the state of an asset, however, if enough information is gathered and the right analysis can be taken from the data, the monitoring system will become more important and the on-site monitoring will be needed less (Maintenance manager).

6.3.3 Standard maintenance part package

In order to increase the points of contact with the customer, while also adding value each step, the standard maintenance part package has been created. It exists for some existing custom vessel already, but is not executed for Beavers as of yet.

The point of this package is to help the customer with the maintenance that is needed. Not only to preserve functionality of the vessel, also due to regulatory requirements.

The reason that this package has been added to the gold tier, is because it alleviates a large part of the maintenance needs of the vessel. As the analysis showed that the customer base has a wide range of professionalism, there is a need for different tiers of engagement. Especially companies or government that have no previous experience with dredging vessels could be assisted by taking the standard maintenance needs of the vessel out of their hands.

6.3.4 Contract

The new philosophy of proactive maintenance and increasing interaction moments with the customers has the goal to increase customer satisfaction and also increase customer retention. A part of this retention can already be created in the contract phase. As mentioned before, certain parts of maintenance can be shipped to customers in time for their scheduled maintenance. This service can be agreed upon in the initial contract, where the customer does not only purchase the vessel and the initial spare part package but also agrees to receive maintenance parts for an x amount of year from Royal IHC, thereby relieving themselves from creating a supply chain of every one of these parts. This would give Royal IHC the financial means to create this supply chain, which can be optimized when more customers opt for this service, which can lead to further cost reduction.

In the initial contract, the services provided by DAS can also be included. This should probably be included as an option due to the fact that while it does help in efficiency, not every customer is willing to pay for these services. This comes from either a need to adhere to a certain budget, which is seen in some starting dredging companies, but it can also come from highly experienced dredging companies that are convinced of their own ability. Therefore, the DAS services are still highly recommended but should not be a make or break, as it does drive up the price without a quantitative return.

On-site monitoring of vessels is another service that should be communicated in the initial contract. It adds to the interaction with the customer in a way where Royal IHC can show their experience. It can be agreed to in the contract that an engineer will visit the vessel every 3 or 6 months in order to do a complete check on the condition of the vessel itself and the spare parts. For the customer it creates an advice in terms of additional spare parts that are needed within a certain time frame. For Royal IHC a report on the condition of the vessel can provide data on wear rates of spare parts. This data can be used in order to refine the maintenance schedule and build a stronger database that could provide the ability to perform predictive maintenance in the future.

An advantage of including these additional services in the initial contract is due to the reason that the additional expenses can be included on the initial loan. Resulting in a contract that does not only provide the customer with the vessel, but assures that scheduled maintenance will be performed in time in order to minimize downtime. It also provides the additional service of advisory services on operational efficiency, vessel inspections on a regular interval and advise on wear part usage and their maintenance strategy.

Lastly, having these services in a contract gives Royal IHC the financial support to actually perform this work, with the financial means that are available to them. Committing to these services is a lot more easy if they are put into a contract compared to performing the services afterwards and having to discuss compensation for each action.

Following from the requirements in section 5, there is no hard requirement for this service to create net profits at the moment. It can, for example, be used to create a good relationship with a customer that might lead to a bigger future order. However, it might also be priced in such a way that Royal IHC will realise a nice profit margin. There are many variables that lead to this decision, however it would be a decent choice to trial this service design with a trusted customer against a reasonable rate in order to test the effectiveness and customer feedback. Ultimately, the pricing lies with the product market group, but the costs are dependent on internal processes. Creating more efficient processes leading up to the service will create the opportunity to generate profits while also offering competitive rates.

6.4 Verification of the design requirements

In this section the design will be checked with the previously stated requirements in chapter 5. In order to check if every requirement is met, the list of requirements will be shown and motivation is provided as to why the requirement is met.

- The parts on the standard spare part list should be classified in such a way that communication to the customer and communication internally is clear
- Create customizability within the standard spare part package to account for environmental operating conditions
- The new service should propose different tiers of service, in order to fill the need of each customer
- The improvements should come from experience and knowledge already within Royal IHC
- The new service design should retain customers for future service requests

- The new service should increase satisfaction for all customers
- A process should be in place that monitors customer satisfaction and feedback in order to improve the service
- Transition from a passive, reactive service, towards a proactive service design
- The new service design should have a more complete operation monitoring in place for customer that want it
- The service design should be able to turn a profit

The first requirement applies to both internal and external communication. However it has to be stated that it originates from internal processes. The proposed classification, as seen in chapter 4, would create an intuitive and understandable method to indicate which parts are in certain categories. This has the ability to avoid miscommunication internally between departments but can also avoid miscommunication with the customer. The confusion or misunderstanding the customer has when they are in contact with multiple people within Royal IHC and they refer to parts in different ways is completely avoidable if everybody agreed on the same way to classify parts. Since this new method to classify parts is a part of the new design, this requirement has been met.

The second requirement mentions that the new design should have the ability to account for different environmental conditions that a customer may encounter. This requirement is marked as a should have, following the MoSCoW method. Meaning that it is not critical to the service design, however it would add additional value if implemented. This requirement is an internal process that Royal IHC needs to implement. As mentioned in the service design, being able to accurately predict the needs of a customer regarding wear parts is the goal to work towards. The implementation will take time, since operational data is needed to create accurate predictions. At the moment this data is not at a point where the wear part usage can be predicted to a certain number. The goal is to start this process and refine it using feedback on the wear part usage that customers experience. This feedback would be used in future cases where the same conditions are encountered in order to create more accurate predictions. The proposed service design has this internal process as a base principle in order to increase customer satisfaction, therefore this requirement is met.

The third requirement states that different tiers of service should be offered to customers. This requirement has been put forward by management of Royal IHC with the following reasoning. It would both create the experience for the customer that the service can be fit to their needs and it would be able to serve the whole range of customers that purchase Beaver vessels. By creating different tiers of service, it can be easier to provide customers with the service elements that make sense for them. This tiered system of service package will be integrated in the sales process of new Royal IHC Beavers, therefore this requirement is met.

The fourth requirement contains internal strength as a guiding principle. Since Royal IHC is in a tough financial situation, resources are scarce 4.3. During internal meeting within the service department it was therefore emphasized that improvements should come from internal strengths. This implies that heavy investment in new competences or techniques are not a top priority, but improvements should come from current competences. This improved design does exactly that, it takes advantage of processes that are already in place. This can be seen in the on-site monitoring improvement suggestion. On-site monitoring is already being done, either from a customer asking for it or from satellite offices' own initiative. Instead, value is created by offering customers this service as a standard option in their contract. The value for Royal IHC is twofold, offering maintenance advice can add sales and this repeated interaction with the customer can lead to an improved relationship. The value for the customer lies in the experience that Royal IHC has, maintenance and operation advice can improve up-time or productivity respectively. This is just one example, but the whole improved design is created to work from the strengths and processes already present within Royal IHC.

The fifth requirement revolves around customer retention. Where customer retention is believed to be too low at the moment by Royal IHC management, this proposed service design aims to strengthen the partnership with customers. Being more involved and let the expertise from Royal IHC be more important towards their operations. Purchase agreements would include steps that Royal IHC will execute for the customer in the foreseeable future in order to help the customer with efficient operation and wanted up time. Regular on-site inspections, delivery of standard spare parts, advice from experts on operational efficiency, and help keeping wear parts sufficiently available. While these proposals would increase possible up time and efficiency, not every customer has the need to operate at maximum efficiency or has the budget to fund these initiatives. A questionnaire has been sent to customers in order to gain insights into their perception of both the current service as well as the service elements proposed in this thesis. The requirement has been taken into account due to added service elements that add possible performance gain for customers. Customers that are satisfied with the services from Royal IHC would be more incentivized to return to Royal IHC for future business or service needs.

The sixth requirement notes that the new design has to increase satisfaction for all the customers. Whereas the satisfaction would be increased from the added service that the silver and gold tier have, the bronze tier would remain largely the same as the current service. It would remain a lower cost service package that provides spare parts that keep the vessel operational for at least a year. Whereas the core services offered will remain the same, due to improvements to internal processes, the efficiency or cost of Royal IHC services could improve for all customers. Customers enjoy the benefit of having the option to let Royal IHC help them improve their maintenance and operational performance, while also having to option to keep support at a minimum and using Royal IHC for only specific value adding processes.

The seventh requirement is indicated as a nice to have. Currently customer satisfaction is measured periodically, however, the information is low in quantity. This low sample size means that it is hard to draw actual general information from these surveys. The questionnaire that is included in this thesis is not an actual part of the new design. However, it is encouraged to implement a feedback system for customers via the provided questionnaire. This requirement is therefore not found within the design, but it is handled in this thesis. For actions towards implementation, view section 4.18.

Requirement 8 is concerning the transition from a passive towards an active role in the service process. The benefit of this change has already been examined. However, does the proposed design put forward a structure that offers enough opportunity to be a proactive stakeholder towards a customer? Yes, multiple element within the service design offer opportunities to Royal IHC to become proactive towards customers. The combination of operations and on-site monitoring is a big piece to this puzzle. Royal IHC would be much better informed about the current state and needs of a vessel. Being able to actively recommend maintenance or upgrade opportunities would be a result of this. Another piece to becoming proactive is by executing the standard maintenance part program. It shows the customer that Royal IHC is more than just a manufacturer, but it can be a partner in the operational life as well. These pieces show the opportunities to become more actively engaged with the customer in a way that also adds value. It can be noticed that these proactive elements only appear in the silver and primarily gold tier. The reason for this is the fact that not every customer wants or needs this extra service from Royal IHC. They either have their own service programs in place, or operate in a run-till-failure way.

The ninth requirement asked for a functionality in the design regarding more complete operation monitoring. As shown in the design, operations monitoring and on-site monitoring has been coupled in order to amplify the amount of relevant information Royal IHC can provide to their customers. Just like requirement eight, the bronze and silver tier do not have this functionality. This is due to the same reason that not every customer would want this functionality, either because of the extra costs or because they do not see the additional value.

The last requirement indicates a desire to turn a profit. This requirement is classified as a should have, since it is not critical to the service. However, as indicated before, the design has a much higher chance to be implemented when there is an actual net profit. There are many variables that contribute to this profitability, many of whom are opaque due to internal processes or due to processes that are not being done at the moment and are hard to assign a value to. The profitability will be shown when a trial run of the service is executed for a customer. All the markers for a profitable project are there, since it largely relies on already existing processes that are being refined. However, as mentioned before, the pricing decision lies with the product market group and they have various other aspects that will determine the pricing of the Beaver products and services.

6.5 Stakeholder implications

The proposed improvement to the service structure can lead to tensions between stakeholder within but also outside Royal IHC. It is important to be aware of those tensions for effective implementation and to be able to solve issues that arise. Figure 28 has already been discussed in chapter 4. This figure is still applicable to the situation with the created service design. However, some relations are added and additional tensions are created between stakeholders.

The proposed service structure would not only encourage, but demand closer cooperation between departments. Each of the proposed service related action within the service tiers is already being done by Royal IHC to some degree at the moment. Combining all these tasks in one service package will require closer cooperation between the departments that are responsible for those actions. Some of those actions require resources from departments that may have different intentions or goals, resulting in tension or conflict.

An example of this tension is found in the gold tier. Inventory management, a system where customers have access to important spare parts that are ready to be delivered, can be an expensive investment without direct value stream. This can create tension between the finance department, warehousing and service department. It can be worthwhile to communicate between those departments beforehand, in order to prevent conflicts.

6.6 Implementing parts of the proposed service

The proposed service is designed to be implemented as a whole. However, it can also be partly implemented. If one were to take the design apart and divide it in parts that could be implemented alone, a couple of options would arise. In this section, the main design features will be highlighted that could be implemented on their own, or not at all. The design has been created with all features in mind, so if the performance of the service as whole is impacted that will be highlighted.

6.6.1 Operation monitoring

The first big feature is the monitoring infrastructure and systems. A big part of transforming the service from a passive to an active mentality lies within the way the monitoring takes place. Right now, monitoring systems lack follow-up with customers about vessel improvements or maintenance. Physical monitoring often does not result in actionable reports or communication with every stakeholder. The idea of the service is that by creating a closer cooperation between both operations monitoring and the regional offices that are responsible for the actual physical inspections of vessels, the resulting combination of information can offer a lot to both Royal IHC and customers. Royal IHC can make sure that spare parts are readily available and maintenance requests can be handled more efficiently, since there is aforementioned knowledge of an order that will be placed in the near future. The customer benefits due to the knowledge of Royal IHC regarding maintenance of the vessel. This is not just the physical state of spare parts, but it is also the experience and knowledge of the supply chain. A certain part might still be in a decent condition for at least four more months after which it would need to be replaced. However, if that product has a lead time of over three months, action should be taken earlier than a customer might think. This is where Royal IHC can add their value to the operational availability of the vessel.

In order to make this combination work, a couple of stakeholder would need to make agreements on the specific conditions. The maintenance part of Royal IHC Services has people that focus on the operation monitoring software. Regional offices have engineers on staff that will visit customers and take a look at the vessels. Inventory managers would need to be involved in order to create a fitting policy on spare part inventory and under which circumstances certain parts can be pre-ordered in case a order is expected to happen soon. Superintendents that have a lot of knowledge on the operational aspects and actual maintenance requirements on board of a vessel should be in the conversation, due to the fact that in reality things are a bit skewed from the expected conditions. The experience and knowledge of these superintendents can not be understated. These stakeholders need to create agreements on what information is needed by whom, which communication lines are needed and what processes are needed to create.

The actual investment would not be unreasonably high, since most of these processes are already in place. As mentioned before, operation monitoring and physical monitoring is already being done. It is just an optimization of the processes that are already there and to capture additional value for both Royal IHC and the customer.

6.6.2 Standard maintenance package

A large part of the proposed service lies in the new standard maintenance package. The goal of this package is to take much of the maintenance need of the vessel away from the customer. This way, Royal IHC is seen as the service provider and not solely as the manufacturer of the initial product, encouraging further service requests to go via Royal IHC.

A difference between the operation monitoring is that this service is not being executed on a larger scale yet. Royal IHC can provide any parts requested by customers, but executing maintenance programs is only done in few cases.

It would take resources to create this service on bigger scale. For example, inventory management should account for these parts and all vessel who need them at which time. But also logistics and installation of the parts are something that should be kept in mind. Previously, management within Royal IHC has said that since OEM parts are not a core competence or high added value of IHC, these parts should not be offered to customers. The reason is that customers will have cheaper alternatives closer to their operational base. Many of these parts can be bought in any country at most industrial stores. Whereas this line of reasoning is correct, this design still chooses to include such a service. That is due to the fact the service does not only serve as something to turn a profit. It can showcase the expertise of Royal IHC and take the burden of maintenance away from the customer. It showcases Royal IHC as a partner that can be used for any maintenance request, thereby connecting customers to Royal IHC for service parts that Royal IHC does have high added value. Lastly, the fact that there is no added value for OEM parts at the moment comes from cases where a customer at the other side of the globe orders only 2 or 3 parts. The invested time and logistics would often cost Royal IHC money on such a product, since the margins are low. Compare this to the case where Royal IHC will offer to execute all planned maintenance for customers. Economies of scale start to kick in, especially in the logistics part. There would be opportunities to couple all maintenance parts that are to be replaced at the same time, thereby seriously reducing transportation costs.

The service could be implemented without this standard maintenance package, however the end result would take a hit. The goal has been to increase customer retention and Royal IHC can do this by showcasing their expertise and increasing customer satisfaction. Without the standard maintenance package, there would be less moments of interaction and the customer would engage more with other companies about parts and services.

6.7 Sub-conclusion

This chapter has shown the requirements that the improved structure should adhere to. The requirements came from technical, customer, and company wishes or needs. Based on these requirements a tiered service has been designed. This tiered structure allows Royal IHC to create extra value for customers that are interested, however it does not increase prices for customers that are satisfied with the current service. This is important because the range of clients for Beaver vessels is quite large, which means that there is not one ideal solution. This tiered system gives customers the freedom to decide what type of partnership with Royal IHC suits them best.

The relations between certain stakeholders within the service process should not be overlooked. Offering a service to customers creates an expectation of service that has to be reached. Closer cooperation is therefore needed. Communication has historically been a weak spot in the organisation and that is important to keep this in mind, especially if departments have different views or goals.

The service design has been checked against the requirements stated in section 5. It has been shown that all requirements are satisfied in either all or some of the service tier, as initially agreed upon. Lastly, a method has been explored to implement parts of the proposed service design. If, for whatever reason, only certain parts of the design are to be implemented. The main stakeholder are discussed, as well as possible effects on the service as a whole.

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7 Evaluation of the service design, using a case study

As mentioned in chapter 6, the design should both be verified and evaluated. Since it has already been verified that all the design requirements have been implemented in section 6.4. The design will now be evaluated. In order to evaluate the design, historical service data from similar vessels will be used in order to determine if such a service would work within Royal IHC.

7.1 Evaluation choice

We evaluate the solution by providing a case study from within Royal IHC. While case studies can be used as a validation tool, in this case it is used as an evaluation tool. This thesis has made the decision to use this particular case study to evaluate the addition of the standard maintenance package to the service design. An evaluation based on a case study is not the strongest validation tool, and the results will therefore not be as strong, however general conclusions will indicate the viability of such a service under the right circumstances.

The first reason for picking a case study evaluation is that this particular case is very relevant since it executes a service similar to the proposed one. It is also being done in an environment where the external factors can be controlled reasonably good, since Royal IHC is executing both the operation and maintenance side, eliminating control from outside actors, and making all data available to Royal IHC.

Another reason is due to the fact that validation is best used to compare experimental results against a baseline of data. Since this thesis designs a service design, implementation is not yet done. Therefore, relevant data is not available on the effectiveness of the proposed service, making it hard to compare it to the current service using quantitative data.

Case study evaluations should have certain "basic generic qualities", according to (Wilson, 2016).

- They are particular, they show events in a particular situation that already exists.
- They are holistic, case studies have many variables with descriptions of their context. There are different features and forces that present views from all involved stakeholders.
- They are longitudinal. In most cases, case studies are of a dynamic nature and are able to tell a story over a period of time, not just a single instance or timeframe.
- They are qualitative. Case studies do not limit themselves to quantitative data, they include images, analysis and present documentation from event, artifacts or quotes.

This internal case study fits all four of these basic qualities. It portrays the situation as it is currently, there are many variables that are at play within this case. Not all of whom help with the validity of the comparison, more on that later. The case is longitudinal and the qualitative element is reached by interviews, data sets, images and other documentation.

7.2 Standard maintenance package

The proposed service design has elements that are already existing processes within Royal IHC. However, these processes are now contractually agreed upon with the customer in order to leave no confusion about the service offered by Royal IHC. One element of the service is relatively new, the standard maintenance package. This package would supply the customer on time with all the maintenance parts required from manufacturers and certification agencies like DNV.

Starting with the basics, the planned maintenance systems already exists. As explained in section 4.8, every Beaver vessel comes with a planned maintenance system that indicates when each part requires maintenance. This planned maintenance comes from two indicators, either a certain amount of running hours or a time interval, whichever comes first. The maintenance is not only strongly recommended to avoid failure, it is required by the certification office. The maintenance required is indicated as a "job" by Marad, the software used for this PMS. Every job has a part connected to it, plus the aforementioned maintenance schedule.

Since the planned maintenance system already exists and is used by the installed base, this becomes a foundation on which the standard maintenance package can be build. The standard maintenance package exist solely of the parts mention in the planned maintenance system.

In order to check the readiness of such a package, and the ability of Royal IHC to deliver and install such a service to customers, the Jordan project will be taken as an example. As mentioned in section 4.9, Royal IHC has a three year service contract in Jordan. It maintains the three Beavers that operate nearby the red sea which are responsible for clearing up salt sediment. The reason that this project is taken as a benchmark for the proposed service is due to the fact that Royal IHC has all the information available, and the service provided is similar to the service proposed by this thesis.

The fact that Royal IHC has this pilot where a complete maintenance program is being executed means that all information is already within the company. This is valuable, since it can show that under certain circumstances, these maintenance projects fall within the competencies of Royal IHC.

7.2.1 Merits of comparability

The similarities between the proposed service design and the project in Jordan are striking. Royal IHC does all maintenance for the three vessels according to the planned maintenance schedule. This means that the up-time performance of this project is reflective of the effectiveness of the PMS. Of course, the planned maintenance is not the only aspect contributing to up-time, since incidental failures will still happen. This has to be remembered when interpreting the overall up-time metric. However, the goal of planned maintenance is to limit the risk of parts failing due to excessive wear or tear. So PMS does play at least a role in reducing failures that way. Unexpected failures will still need to be resolved and the current processes of Royal IHC Services can be used for that, by making a request of the required part.

The operating method for the site manager was basic in nature, check the PMS system for maintenance jobs coming up and group them in order to prevent unnecessary downtime. The two main maintenance tasks that could not be prevented or extended were the changing of the engine oil and an overhaul of the engine. The engine oil needs to be changed every 1000 working hours or every three months, whichever comes first. Since the vessel operates 24/7, the 1000 operational hours would happen way before the three month mark. Therefore, this maintenance would happen almost every six weeks. In their experience, this window every six weeks of forced downtime due to the changing of oil, offered them enough opportunity to complete other smaller maintenance tasks.

The overhaul of the engine is scheduled to happen every 9000 operational hours, and is expected to take between two and three weeks to complete. This offers the perfect opportunity to perform other maintenance jobs that take some time to complete, as the vessel has forced downtime anyways. The experience is that this grouping of maintenance tasks positively affected the overall up-time of the vessel. With the smaller moments of maintenance during the changing of oil and the moment for big maintenance during the overhaul of the engine, the Jordan project has shown that maintenance can be executed efficiently and effectively.

The results of the Jordan project are positive. with up-time percentages of 92% that have been reached during the project. This contract had the up-time as a metric to judge performance. The contract stated that 75% up-time was the goal, which has been achieved and outperformed.

7.2.2 Limitation of the Jordan project

In order to judge the results, the circumstances under which the results have been achieved should be stated. Especially, the factors that would influence the performance of a similar service contract under different circumstances. The circumstance in Jordan are unique in some aspects, which will be discussed below.

First difference between the Jordan project and other Beaver use cases has to do with the intensity of usage. Due to the 24/7 usage of the vessel, the 1000 hour limit is reached earlier than the three month mark. In other cases, where operational hours lie more toward the 40 hours per week, the three months will be reached earlier than the 1000 working hours. This moves the efficient maintenance window that the project in Jordan benefited from. The argument can be made that not only the changing of oil but also the other parts that accompanied that maintenance moment in Jordan are being moved in the same way. This would certainly make sense and the PMS software would indicate that this is a possibility. However, this difference should be noted and considered when extending the maintenance service across different use cases.

The second difference or limitation of the Jordan project has to do with the size and goals of this project. Since there is a three year contract in place, an office and warehouse have been located nearby and personnel has been assigned. As mentioned, the vessel operates 24/7 and at all times there are three employees of Royal IHC on board of the beaver 65's and two employees on the Beaver 45. The operators are from the client, but the mechanics, deckhands and bosun are all personnel of Royal IHC. This increases the information coming from the vessel and the fact that the office and warehouse are located very close means that whenever something happens, a solution can be implemented quickly. The reason for this setup can be found in the way the contract has been created. Using up-time as a performance metric means that Royal IHC has up-time of the vessel as the highest priority. As the project experienced high up-time this way of operating makes sense for this use case. This also marks a difference to smaller projects that do not have multiple vessels that require maintenance. According to a maintenance manager, creating the infrastructure comparable to the project in Jordan is financially not feasible for dredgers with only single vessels. While this is quite logical, there is an argument to be made that the goals for many dredgers across the globe are different compared to the Jordan project. Whereas this use case primarily focuses on up-time, the proposed maintenance service aims to alleviate the burden of planned maintenance from operators. While up-time is still an important metric, the maintenance package is just a service that makes sure that planned maintenance is done in time. The overall up-time decreasing due to failures that are not directly caused by maintenance from Royal IHC would not fall under the responsibility of Royal IHC, since the package is not a total service guarantee.

A third difference between the Jordan project and other Beaver vessels are the environmental factors. The weather conditions are extremely dry and hot. The water and soil is very saline, as the vessels operate next to the red sea. While most parts that fall under planned maintenance will not be impacted as much by these conditions as others, there are parts that degrade faster or slower because of the environmental factors. This is a factor that should be taken into account when offering the standard maintenance package to customers. When operating in extreme conditions that are known to increase wear on maintenance parts, contractual agreements should account for increased maintenance in case it is needed. This factor will be most challenging when starting the service, as the knowledge and experience is still being build up. However, in time better maintenance estimates should be established that take environmental factors into account.

The fourth big difference is that all Jordan vessels were new when the project started. While this proposed design is primarily meant to increase the service towards customers that purchase a new vessel, there is a large installed base which might be interested in this service as well. The big difference is that the Jordan project is using new Beaver vessels build for this project. The overall state of older vessel can be very different compared to vessels that only have been around for a year or two. Since Beaver vessels can be operational 30 years after construction, there are large gaps in the overall state of maintenance between vessels. It is to be investigated by the planned maintenance systems part of Royal IHC in combination with superintendents if a workable maintenance program can be created for previously sold Beavers. Ideally, this standard maintenance service is to be performed on new Beavers initially in order to create the proper processes and infrastructure to make it work. When the concept proves to be feasible on new vessels, the service can be extended to also include older vessels, since it is too big of a market to ignore simply because the vessels are older.

A last limitation of the Jordan project is that is only one project and there are only two types of Beavers maintained. The results from this project are positive, however it is important to note that it is only a single project, which only performed maintenance on 2 types of Beavers. There are five different types of Beavers in the current range of whom three were not included in the Jordan project. Due to the similarities between the different types of beavers, it is not too far fetched to assume that similar results could have been achieved with the other types. However, there is no proof that that would have been the case. Similarly, it is only one project. While the results were positive, it is hardly a substantial or reliant sample size to claim that the maintenance service works flawlessly. In the Jordan case, the maintenance service contract worked out and it offers the perspective for Royal IHC that under the right circumstances, similar results could be achieved.

7.2.3 Evaluation of the standard maintenance service

The Jordan project has shown a great potential for further servitization activities of Beaver vessels. By offering to perform the planned maintenance for the customer, Royal IHC alleviates the burden of all planned maintenance for customers. Results in Jordan have shown that very high levels of up-time can be reached by a very close way of cooperating with the customer. The scope of service in this thesis is not as far reaching as is the case in Jordan, because the proposed maintenance service is limited to performing the planned maintenance. The Jordan project has shown that Royal IHC can perform the planned maintenance tasks successfully and on time.

While multiple of differences and limitations have been shown, most can be contributed to the fact that the Jordan project had different objectives compared to the intended service in this thesis. Where the Jordan project had to anticipate on every maintenance issue due to the up-time focus, the proposed service will only focus on executing scheduled maintenance of predetermined parts at predetermined time intervals. What the Jordan project did show is that when tasked with executing this scheduled maintenance, Royal IHC can perform to the highest standards.

While this case study is similar in many regards, there are also crucial aspects that will differ in the implementation of the proposed service design. It is for this reason that while this case study shows great potential, it can not be taken as a guarantee to success.

7.3 Sub-conclusion

To evaluate the improved service design, the standard maintenance part package has been compared to a project that is currently underway in Jordan. This project shows that Royal IHC can perform planned maintenance in an effective and efficient manner. The Jordan project goes further than the proposed maintenance service, as it does all maintenance, including non-planned maintenance. However, all elements of the proposed service are included in the Jordan case.

There are also limitations that this Jordan case cannot directly solve. Issues like number and types of vessels, environmental factors, controlled environment, and usage intensity are only seen from one perspective. These limitations are not only mentioned, reasoning and arguments are provided to prove the concept and offer solutions.

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8 Implementation plan for the different service elements and recommendations

In figure 40, the position of this chapter, within the structure as a whole, is indicated. The service design has been created and evaluated in chapter 6 and chapter 7 respectively. Which leads to this chapter, the implementation plan.

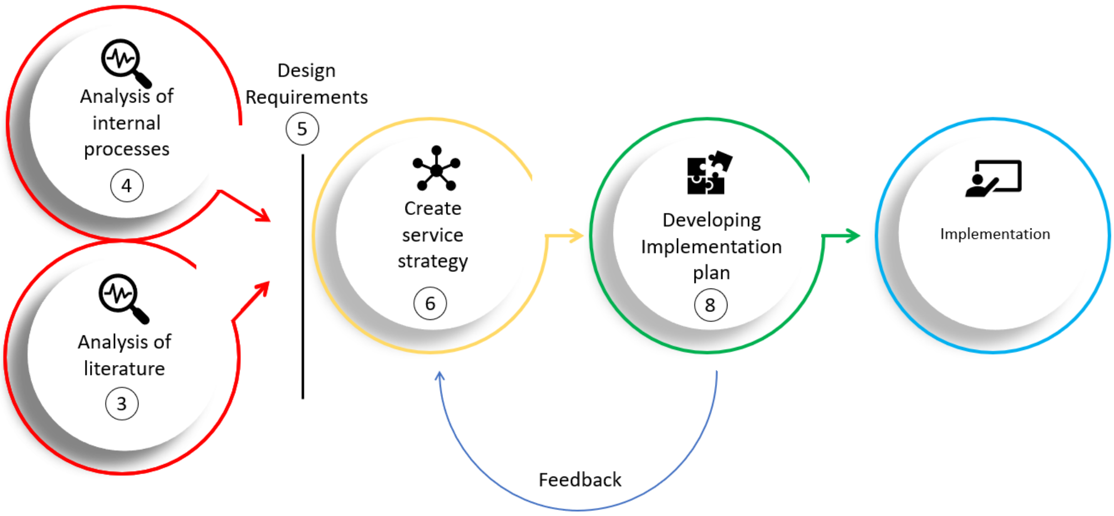

Figure 40: Design process, with chapter indications included, inspired by (Tschimmel, 2012) and (Li et al., 2020)

In section 4.18, recommendations have been introduced that could provide better customer satisfaction, more efficient processes or both. This chapter will further analyse these recommendations and explore the implementation. In figure 41 the impact for each recommendation is shown on the Y-axis. At the same time, the X-axis shows the relative cost that accompanies said initiative, these estimates are created by both company employees as well as the author. The initiatives with a high impact would be rated in such a way due to factors as, customer satisfaction, process efficiency, and cost reduction. An initiative lower on the impact axis does not mean that there is only little improvement to current practices, it is indicative that its potential is not as far reaching as initiatives rated higher. It should be noted that the impact and cost axis is reflective of Royal IHC, an initiative with high impact means that there is a lot of potential for Royal IHC. The estimations on the impact and costs are a combination of reasoning from the author, as well as arguments from relevant stakeholders, indicated at each recommendation.

There are three recommendations that are placed on the right side of the figure. MyIHC, Predictive maintenance, and up-time based contracts. These subjects will be analysed in section 9.5, because these are subjects that show great opportunity. However, the steps that need to be taken for successful implementation are still either too expensive or knowledge is missing at the moment. Therefore these subjects are handled in the recommendations part for future research.

Low hanging fruit is the term for opportunities that are easy to implement, while providing some use. After the analysis conducted in this thesis, some recommendations could be considered low hanging fruits. Creating contractual agreements with suppliers is one process that would not require much investment or completely new processes. In fact, it could be implemented tomorrow. Same goes for the internal communication and the knowledge about internal processes. Both these recommendations could be initiated tomorrow by the stakeholders indicated in order to

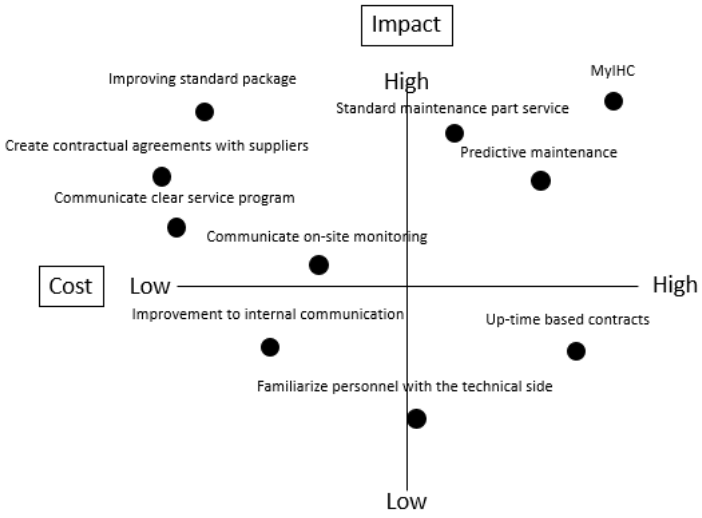

Figure 41: Implementation of the recommendations and their perceived cost/impact

start the process.

8.1 Standard spare part list

The standard spare part package has opportunity to be improved upon. The opportunity, or the impact, is rated high. This high rating comes from the improvement it can have for the competitive position for Royal IHC in the sales stage, plus the fact that it opens the door for the customer to engage in a stronger partnership regarding maintenance and service needs during the operational period of the vessel. This high potential has been resonated by a sales manager, who indicated that an initial package that better suits a customer will give Royal IHC an edge in the procurement phase. Increased sales would benefit both the company as a whole, but the service design would also benefit from economies of scale. It is for these reasons that this initiative is ranked this highly.

The costs are indicated as low to moderate. An indication for this is the fact that it is basically a variation on the package as is it today. Time and interaction between multiple stakeholder is required, however new competences or processes do not need to be developed. It is for this reason that the cost is indicated as low to moderate.

The current spare part list has a couple of issues that that can be improved upon. For example, the term critical part is applied to certain parts without clear definition or rule-set. In order to alleviate this issue, a multidisciplinary work group has been formed. The goal of this group is to create a clear formulation of all types of parts and the rules on which they can be assigned. Therefore, this group has to determine exactly what elements connects a part to a part category. The idea is that the results from this group are setting a standard that is adopted within Royal IHC. It should solve communication issues, caused by people using different terms for the same parts. The communication errors therefore cause, a slowing down or even the mishandling of certain processes. It could also create a clearer picture towards customers, if each contact point within Royal IHC uses the same terms for each part, communication towards the customer will be less prone to miscommunication. This group has had multiple meetings and both the classification, criticality, and the implementation in the ERP system show good progress. It is advised to keep this process going and complete the pilot, which is being done on a Beaver 50.

Another issue is the communication within departments in the service process. Sales has indicated that basic information on previously sold vessels is inaccessible to them. Resulting in time loss due to communicating for extra information from other departments.

An integral part of selling a product plus a service is convincing the customer that Royal IHC has both a quality product and the intention to work with the client, instead of just making a quick profit. Sales has indicated that preliminary conversations with customers often explore the goal of the vessel, competition, and future plans of the company. In these conversations, a type of Beaver can be recommended based on all affecting factors. As explained in chapter 4.18, the type of soil a customer expects to encounter can play a big role in this decision. Having such a cooperative sales process followed by selling a standard spare part package is a missed opportunity. The reason that this is a missed opportunity is due to the customer expectations. Royal IHC tries to find the ideal vessel for the customer regarding soil conditions, production requirements, environmental effects like waves or long distances to shore. Matching the customer to a vessel that optimally fits their needs and then offering a standard package that does not account for any of the previous considerations is a missed chance.

Instead of a standard part package that functions as a one size fits all, some attention towards the expected operational profile of the customer should be given. Different soil types require different tools in order to perform to specifications. In order to create a fitting spare part package, it is logical to approach it the same way that the sales department determines the best suited vessel for a customer. Create slight differences in the package, depending on the operational conditions that the customer can encounter. Circling back on the earlier established categories from chapter 4.12.1, the customizability should lay in the wear part category. The reason that parts from other categories do not need to be changed between different customers is that these parts will not show significant extra wear in different environmental conditions. However, the wear parts interact with the soil and other environmental conditions, seriously impacting the lifespan of these parts. According to a regional office manager, in the Middle-East a dredge pump can be worn out in a month, whereas the same pump can work for a year in other places (Regional manager, personal communication). The current package does not make a distinction between both locations, and therefore delivers the same components.

8.2 Standard maintenance part service

Royal IHC could focus on becoming a strategic partner to customers, instead of being the provider of the initial product and some initial spares. The largest part of Beaver customers are companies or governments that are inexperienced in the dredging industry. This is an opportunity to assist the customers using the knowledge and experience Royal IHC has with the Beaver products. Being able to perform the scheduled maintenance for customers has the ability for Royal IHC to get more interaction with the customer and share the experience that they have.

In order for this standard maintenance part service to work, multiple stakeholder need to create a workable solution. Planned maintenance employees have knowledge of the parts within the maintenance schedule, purchasing will have the pricelists available, and superintendents might have experience about particular maintenance that is either redundant or not being carried out often enough, despite with the manufacturers claim. The legal department would have to be involved with the language of the contract, because with such volatile prices and lead times of suppliers, there is a substantial risk if services are exchanged for a lump sum.

The Jordan project has already shown great potential, however there are quite a lot of resources invested in the project. If would be advisable to first do a trial of this service with a smaller sample size, instead of introducing it with all new vessels. The experience and knowledge of that first trial will show in what capacity Royal IHC is ready to implement this service on a bigger scale.

This recommendation is rated as high impact due to its potential of generating revenue in an area where currently only a fraction is generated. The opportunity to stay involved with the maintenance of a vessel provides Royal IHC with a constant source of revenue after the initial purchase. Not only for vessels that are sold now, in the future this service could be expanded to vessels already in the installed base. This would allow Royal IHC to significantly increase their part sales.

The costs are marked as moderate, this is due to the fact that parallels already exists within Royal IHC. Other vessels often get sold with a maintenance service included, and the Jordan project has shown that under certain circumstances, Royal IHC can also set up and execute such a service for Beaver vessels. This leads to the indication that in order to develop this initiative, a moderate amount of resources are needed, since the capabilities exist within the organization, but there is still quite some investment needed. For example, processes need to be initiated, possibly increased maintenance staff or contractors need to be arranged. Better agreements with suppliers is also an aspect that should be researched before fully committing to this initiative.

A distinction has to be made regarding the investment for the initiative when it is being rolled out. There will be a lot of costs related to keeping inventory and transporting parts globally, however at that time revenue from customers should also flow towards Royal IHC. So the costs that are discussed here are purely related to implementing the service, not carrying out the service.

A critical point is the adoption rate. The experience within Royal IHC is that most customers do not order their regular trade parts from Royal IHC but they purchase them at a local store. This standard maintenance part service would unburden the customer with the sourcing and installation of their regular maintenance parts. However, since the experience is that customers not order many of these parts at Royal IHC currently, it is to be seen if there is a market for this service.

8.3 Communicate a clear service program the the customer

Include the sales team in the operation to create a clear service program. The new design has to be communicated clearly towards every potential customer.

It would also be crucial to show that Royal IHC is more than just the supplier of the initial product. The customers need to understand that Royal IHC has additional services that can take work out the customers' hands, like the standard maintenance package. But it can also assist in creating more efficient operational processes, through additional training or operational analysis from DAS. This has to be communicated in a clear manner to customers, since dredging companies or governments with limited experience might be interested in these additional services. Another big customer group that might be interested are companies that use Beaver vessels but are not in the dredging business. For example, certain mining companies will use a dredging vessel during their mining operations, due to dredging not being one of their competences they want to outsource as much of the activity and maintenance as possible.

This initiative is marked as a low cost, since it should only involve a meeting in which the service program is explained to all involved stakeholders, especially the sales team. Afterwards, the sales team and other stakeholder will understand the most important selling points and be able to communicate that effectively to the customers. Therefore this is a relatively low investment. The impact is rated moderate, this is because a clear messaging can inform customers without overwhelming them later on with all sorts of additional costs or investments. Customers might appreciate understanding the complete picture of after sales service that are available. It is for these reasons that this initiative is judged as a relatively low investment for moderate impact.

8.4 Improvement to internal communication

Certain parts of the service and maintenance chain have very little or no communication. Resulting in the same work being done by different department, parts of information not getting to the right people, and overall not having a mentality that the service chain is one department, just a combination of fragmented teams that do their own things. The same work is being done twice and information does not flow as freely as would be ideal.

Employees have indicated that it seems like the ERP system is not designed to work in such a way that good communication and sharing of information is possible. One of the reasons would be that due to reorganizations, people have been taking on additional work, departments have been split or merged and crucial people have left the company. It might be that the ERP system should be modified to have additional ways for after service to share their information and communication, however it is not necessarily true that all these problems are caused by the ERP system. Managers and experienced personnel from all departments of the service chain should create a workable workflow that makes sure that the relevant information gets to the right people, while the information is preserved and can be found by anyone that needs it.

The service design presented in this thesis has included communication lines between departments that should work more closely together, since they would perform better by sharing information instead of working within their own teams. This initiative is rated low to moderate in impact, which is due to a certain level of unknowns within the service chain. It is not completely clear where work is being done twice or whom is not receiving all information they might need. However, it is clear to the author that the whole service chain would be more efficient if these lines of communication were improved upon. The costs that would accompany this improvement range from low to moderate since it might take many meetings to find out which personnel actually has problems getting to certain information. Or before finding out that two different departments do the same tasks independently from each other without knowing.

8.5 Communicate on-site monitoring and assessment of vessel and equipment by Royal IHC maintenance crews

On-site monitoring is a process that can give a huge amount of information that is invisible to operational monitoring systems. While the monitoring systems measure production, operational hours, and other values, an actual visit of the vessel shows the actual state of it. Cutterheads can be inspected, integrity of the construction is visible and measurements can be taken that the operation monitoring systems cannot measure. This opportunity is twofold, as explained in the service design. This visible information from the visit plus actual conversations with the crew about the jobs, state of spare parts, other issues that they came across, etc. This information can be combined with the operational monitoring systems to increase their functionality. A maintenance manager has indicated that currently many measurements are being taken that do not actually have an output that can be quantified. However, with additional information, these signals might indicate actual information about the state of certain parts or the vessel as a whole. Therefore, the stronger cooperation between these two departments will both make the operation monitoring systems more accurate and more relevant. The additional effect that the new service design has, is the predetermined visitations to the vessel by Royal IHC engineers. This gives a structure for both Royal IHC and the customer to plan and account for these visits.

The aforementioned planning serves as an opportunity for Royal IHC and more specifically, the regional offices. A new process should be created where the visits of vessels have to standardized. This would allow for structural information that can be compared and checked over several different vessels. Another advantage is that with a standardized way of work, creating the report, or other findings can be communicated more efficiently between the people that need that information. This is a huge improvement over the current way that these reports are communicated, since most of the times they are not made at all. In the few cases that they are, the reports do not get to all involved stakeholders.

This initiative is rated moderate in impact and low to moderate in costs. The impact side is relatively unknown, since right now not a lot is in place to actually work with the extra information that can be gathered from there. Processes need to be in place to get that information to the right places. The costs are primarily due to the increased amounts of work that the on site monitoring staff will need to do. Filling out the reports and sending them to the right people will add a permanent extra load to their work.

8.6 Create contractual agreements with suppliers with the help of the new-build section of the company

The first part of this recommendation focuses on the agreement. It would benefit Royal IHC to create contractual agreements with suppliers for the lifetime of the vessel it produces. Availability of spare parts can be a great mechanism to satisfy returning customers. Just like how the opposite can create great dissatisfaction. Having unservicable parts on a vessel due to a supplier stopping a certain product will create problems for the customer. While Royal IHC has an engineering department that can create solutions for any technical problem, this is both expensive and unnecessary if the aforementioned part would have been available. Therefore, it would benefit Royal IHC to create contractual agreements on the availability of spare parts with suppliers to guarantee availability and limit the risk of problems for the customer with obsolescence.

In order to get a good price for this agreement, Royal IHC should send their biggest asset to the negotiation table. Currently, it is the experience in the service part of Royal IHC, most parts do not have contractual agreements with supplier. This means that employees will have to order the parts individually or other low quantities. This often translates in prices that are somewhat inflated. If, with the design of a new Beaver type, the new-build section of Royal IHC were to negotiate with the supplier, conditions are far more favourable for Royal IHC. First of all, this early in the design, suppliers can be exchanged and other equipment can still be fitted in the vessel. Second of all, Royal IHC has a stronger position, since it is not about a couple of parts. The negotiations are about the parts of all the new vessels for their entire lifetime. Which can amount to quite the total figure. This would certainly create more room for negotiation than the single employee ordering a low amount of spares that is the case at the moment.

This recommendation is more usable for new vessels, since the older models are already locked in with certain equipment of specific suppliers. This equipment is often not able to be replaced with similar parts of other suppliers, meaning that simply switching supplier for better prices would also involve an overhaul of the vessel. Since suppliers are aware of this, it would be hard to negotiate a great price for Royal IHC. However, not being able to get the absolute lowest price is not the only benefit that these agreements have. As mentioned before, it is beneficial to guarantee availability of all parts.

When creating a new Beaver, either a single vessel or a complete new type, the new-build section of Royal IHC should come together with service management and try to include a fitting maintenance strategy before completing the vessel. Creating favorable spare part agreements, which also translate into a great selling point towards customers. This is why this initiative is rated as high impact. The costs are on the lower end, since it will only take communication with suppliers, with the help of the legal part of Royal IHC.

8.7 Give departments the opportunity to familiarize with the technical side to increase knowledgeably on the high tech nature of the equipment

Having people be engaged more in the activities of each other creates a feeling of being part of a team. Having people become more knowledgeable of the technical side can help avoid miscommunication or increase intuition in certain processes. This is an issue that is hard to measure in metrics like turnover or customer satisfaction. However, it is felt within multiple departments of Royal IHC that people are not aware of other departments activities, responsibilities, and abilities. This can be traced back to the company culture of the past, where all business units operated independently from each other. With the new company structure, collaboration and communication should increase compared to the past. However, employees feel that, at least in the service part of Royal IHC, this collaboration and knowledge of other departments is still lacking.

Currently, within the service department, every few weeks the department called Dredge Equipment gives a presentation of around 90 minutes on a technical subject. Dredging pumps, cutterheads and general dredge vessel have all been presented before in order to create more of a technical understanding of what happens within a Royal IHC dredging vessel. This has been perceived positively by most of the people at the department.

An aspect of improvement lies in the scope of the current setup. Whereas currently the technical knowledge of the dredging systems and vessels are discussed, the day to day activities and capabilities of departments is an aspect that employees would like more information on. The service chain has many departments and people involved, yet there is a lot to gain by making sure that people understand what each department can offer and what they are working on. It would be favorable to start this process at the managerial level in order to determine the main targets and capabilities of each department. Then focus on what kind of interaction each department can and should have with other departments. After these key aspects are identified, each department could do a presentations like the ones that the technical department does at the moment. Creating awareness of all components of a departments operations and responsibilities. Creating an environment where everybody understand all aspects of the service chain would allow for a better ability to find the right people, less miscommunication and should therefore result in smoother processes.

This initiative will require a moderate amount of resources due to taking up peoples time. It can be achieved through different kinds of training, but the aforementioned presentations are also a nice way of improving each persons knowledge on the subject. Due to the amount of people involved in the service chain and the vast amount of knowledge there is within Royal IHC on the subject of dredging, this can become quite a time consuming project. Combine this with the fact that not every employee will need to know the specifics of every aspect in dredging and that is where the low impact rating comes from. It will be helpful for sales personnel to understand why certain mechanics in dredging are important, however, they are not to someone that is doing administrative work.

8.8 Sub-conclusion

To conclude, Royal IHC can improve on its service level towards customers in a couple of ways. This chapter has shown that some of the recommendations from this thesis can be implemented tomorrow, provided that the right stakeholders are involved.

This chapter has stated that there are two specific actions that can be taken to improve internal communication and understanding. Making employees more knowledgeable about the technical side of the product can engage employees more with the product and company. It can also create an understanding and shared vocabulary that is used within the company, this decreases miscommunication.

A more technical improvement has been discussed in the makeup of the standard spare part package. Currently the package is based on experience and intuition. A more profound method has been proposed by teaming up all stakeholders and use other metrics like customer feedback and data driven analysis.

Lastly, a method has been proposed to keep purchasing cost of spare parts lower by creating agreements with supplier. The added benefit would be that availability of parts would increase.

9 Conclusion, reflection, and recommendations

This thesis has tried to answer the main design question: 'Improving the current service design for new Beaver® dredging vessels'. In order to design such an improvement over the existing service design, an analysis has been done on the existing processes which has been compared to state of the art solutions.

The results from the analysis were that some practices in place are not used to their full potential. They could in some cases be combined with other processes in order to amplify the use of them. In other cases extra lines of communication would provide better integration of different stakeholders, leading to relevant information getting to the right people.

Following from the mindset where the currently reactive service would be transformed into a more proactive service, the interaction moments with the customer are increased. While, each interaction moment will still contribute additional value to the customer. With the new design, Royal IHC would have a much more detailed view of each vessel in their gold service program, due to the integration of operational and on-site monitoring.

A new service element has been created with inspiration from other Royal IHC vessels. The standard maintenance part package would be able to service vessels with all of the planned maintenance activities during an agreed upon time-frame. This is already being done for other Royal IHC vessels, but not for the Beaver standard vessel. Due to the fact that these vessels are a standard product, creating processes to service these vessels would work all over the world. As seen in the Jordan case, this degree of maintenance is within the competences of Royal IHC in the right circumstances.

Other additional processes like a customer feedback loop, better knowledge transfer processes and supplier agreements will provide additional advantages to Royal IHC as a whole. While not directly being part of the service chain, these processes would benefit departments that interact with the service processes and therefore indirectly affect the service performance. These recommendations are explained and the first steps towards implementation are offered.

From the research done is this thesis, a new service design has been created that satisfies the requirements that were constructed. The service design is transformed into a more proactive tool to add value to the operations of the customer. An increased number of interactions, each of which will provide value for the customer, will add to the experience of the customer that Royal IHC is a reliable and knowledgeable partner.

9.1 Academic contribution

This study has discussed outcomes from various servitization related literature. It has confirmed the discussed outcomes and added a clear design framework to the list. While the design requirements are specific to the company case and other environmental aspects, this study can be seen as an implementation study of servitization in a high tech environment. It shows current opportunities and challenges that a particular manufacturer experiences.

The study has identified specific design requirements on which the service is designed. This design framework can be used in future studies that focus on redesigning a service within a high tech environment.

9.2 Managerial contribution

This thesis has shown a design framework that can be used by managers in manufacturing companies to introduce servitization in their products. An overview of literature on servitization indicated the importance of digitized information. Innovations that allow for these sources of data have been analysed and included or excluded for this specific project based on their relevance. Managers should judge these technologies based on their own company specific limitations and opportunities.

While the design process has some general requirements, other requirements are company and sector specific. In order to translate this design framework to other businesses or sectors, an understanding and judgement of the limitations and requirements is required.

This servitization design is an iterative process in itself. It should be seen as an initial service program that is to be improved upon continuously. New technology, additional insights, and changing environments all contribute to a constantly changing industry. Having a strong digitized information platform on which the servitization is build, will help develop further service initiatives.

9.3 Research limitations

Since no research is immune to limitations, this project has limitations that impact the results. Some of these limitations originate from the company setting in which the research takes place. Others come from the fact that there are some specific requirements that created unique, not easily replicable, circumstances in which the service is designed.

There is a dependency on internal knowledge in this project. Many experts and other people within the organization have offered opinions, facts, analysis, estimates, or experiences. All this knowledge has to be viewed with the bias that accompanies those statements. People tend to be overly optimistic on their and the companies ability to perform certain tasks, now and in the future. This information has been included in the thesis, due to the fact that there was no other way to gain insights in the processes of the company (Bogner & Menz, 2009). Understanding that it provides problems regarding the internal validity, wherever possible, secondary sources of information have been used to confirm statements made by experts (E. P. Jack & Raturi, 2006).

Another limitation is the limited generalizability. Due to some company specific requirements, the service design that has been created might be less applicable to competitors or other industries. While the design philosophy and the methodology can be used as a framework to develop a similar service, the service design created in this thesis is based on very specific requirements.

9.4 Academic field future research

This chapter will focus on recommendations for future research in this area. The recommendations are based on the finding from this thesis and questions that arose that couldn't be answered in the scope of this thesis project.

This thesis project has created a service design with the intent to increase customer retention. One of the limitations has been that the expert information is all gathered from within the project company. While this project was not possible without that information, it skewed the results by adding bias. Future research could focus on increasing the sample size of servitization implementation within the industry, thereby lowering the impact of bias from one specific source.

While this case study shows the result of a service under similar circumstances, several factors limit the validity of the result when placed in a different environment or actors. It would therefore be recommended to do a more detailed validation in the future in order to properly validate the results that this thesis shows are possible. While the signs show that the service is possible within the circumstances stated, the case has been used to reinforce this theory and show in which aspects uncertainty lies. When the actual service design is implemented on some scale, results can be taken for comparison with the current service in order to more accurately validate this service design.

9.5 Company specific future research

There are certain company specific opportunities that could provide long term advantages, however they are not at a point where large scale implementation is feasible at this moment. Further exploration of these opportunities could result in new concepts which can enhance the offered service to customers.

The following recommendations show signs of promise, however, they are not yet at a point that larger scale implementation is possible. The following section will review the potential of these recommendations.

- Create an environment where predictive maintenance can be used for Beaver vessels.
- Turning MyIHC into a one-stop-shop for all matters concerning maintenance and performance of a vessel
- Research feasibility and applicability of up-time based contracts
- Implementing a customer feedback loop
- Applying a servitization design to different standard products

These opportunities are chosen due to the fact that they lay within the competences of Royal IHC and have strong opportunities towards the future.

9.5.1 Create an environment where predictive maintenance can be used for Beaver vessels

Currently, predictive maintenance is not offered for Beaver vessels. This is due to the fact that most Beavers are not equipped with any monitoring equipment. New Beavers have monitoring equipment, however this is not yet enough to be able to perform predictive maintenance. In order to be able to perform predictive maintenance, the engineering team has cooperate with the service team to determine what is needed. The service team has to determine what data is needed to be able to recommend certain maintenance activities and the engineering team has to find a way to implement this on new Beaver vessels. It might prove worthwhile to also be able to install these sensors on already sold vessels if possible.

With this information, the service can be improved due to Royal IHC being able to inform customers on maintenance before a possible failure happens. In the proposed service design a path towards predictive maintenance has been taken. By gathering and combining both event data and monitoring data, the maintenance need of a vessel can be anticipated on. This is an improvement on the current process, however it is not yet predictive maintenance. One of the reasons that the path towards predictive maintenance is chosen, but not the full implementation of all kind of sensors and monitoring systems is due to the industry. These vessels have lifetimes of up to, and sometimes beyond, 30 years. Since there is already a large installed base that does not have predictive maintenance installed, a maintenance solution like the one that is proposed in this thesis will work for both new and old Beaver vessels.

There is certainly an opportunity for predictive maintenance in the Beaver product, since it is a standard product that is sold in relatively large numbers. That is why it would certainly be a good idea for the stakeholders involved to meet and set their goals. The people that have been consulted during this project have indicated that certain parts of Royal IHC should be included in this conversation. The maintenance part of Royal IHC Services should be there since they know about all maintenance needs and current processes. Engineers know about the technical makeup of the Beaver vessels and should be able to determine what is technically possible to implement. A combination of superintendents or service engineers can provide expertise on the output signals that are important to measure, since they have first hand knowledge on maintenance and the actual work conditions that these vessels operate in. Lastly, the digitization part of Royal IHC might be included in order to create or choose a suitable digital environment to conduct the predictive maintenance in.

The biggest challenge lies in the fact that while the Beaver vessel is a largely standard product, it does not operate in the same conditions. This can make it hard to compare the same Beaver model when it is operated in different areas. Some of the measurements that are used for predictive maintenance, like vibrations in the engine or pump will work regardless of environment or activity. However, there will always be different external factors that influence the data that all these sensors transmit. The main challenge is to gather the data in such a way that it limits these external factors. Some of these factors are the skill of the operator, weather conditions, soil type and the type of operation.

As mentioned before, there is a real opportunity to improve the product by implementing predictive maintenance, however it is a choice that needs to be made by management. Since Beavers are a standard product, any change in the product will impact its place in the market. Beaver vessels are an affordable and compact solution for many dredging activities. The added costs from this extra functionality of predictive maintenance might negatively influence the market position due to the increased price. It is this dynamic that requires further research within the company on the ability to implement predictive maintenance with the indicated relevant stakeholders. It will also require a decision from management on the path forwards and if predictive maintenance is a part of that.

9.5.2 Turning MyIHC into a one-stop-shop for all matters concerning maintenance and performance of a vessel

The potential for such an application is quite large. As explained in chapter 4.15, the idea is to fill the MyIHC application with all service and monitoring information that is available. It would allow owners to monitor the main performance numbers and figures or single vessels or their entire fleet. It would also function as the place where service requests can be requested. The service request would become more transparent because all serviceable parts on the vessel would be included in the application with accurate and up to date pricing.

The possibilities that will help the customer are certainly there. All serviceable parts will be available in MyIHC, with up to date pricing, lead times and available stock. Integration with the maintenance schedule of the customers vessel is one of the possibilities that flows from this. For example, if the customer wants to purchase some wear parts for a project in the near future, the system can point to additional maintenance opportunities. If some part needs to be replaced in 6 weeks while the lead time is 5 weeks, the system will alert the customer to the opportunity to purchase it together with the requested wear parts, thereby preventing unnecessary downtime or failures.

In order to make this application work, a lot of moving parts need to be put together. First of all, the data on which the application operates needs to be complete and up to date, to avoid confusion and frustration. Secondly, there are multiple stakeholders that ultimately interact with the application. Lastly, the customer is arguably the most important user of the application. While superintendents or service employees may interact with the application, the underlying data is already in the Royal IHC infrastructure. It is primarily a window for the customer to gain information on their fleet or look into the available service options from Royal IHC.

It should be the responsibility of Royal IHC Services to keep the part data up to date. Prices, lead times, manufacturers, and logistic data should be properly documented and accessible for the application. While the new-build section of Royal IHC can assist in creating long term agreements with suppliers, the part data would still fall under the responsibility of the service part of Royal IHC.

It has been mentioned briefly before, but there are multiple stakeholders involved both in the development and the operational phase. At the very least, the end users should be a part of the development program because their input might be very useful. A superintendent can provide information on what data is most important to him, which can be shown conveniently in one display. While the output in this example could also be changed afterwards, there will always be things that are overlooked by other departments, regarding the operational usage of the application by a superintendent, if a superintendent is not included in the development. This is why at the very least, all end users should be able to provide the inputs and outputs they expect from their point of view. Lastly, the financial side is quite important here. Developing an application can become expensive and with the current situation of Royal IHC, this can be troublesome. Developing this application for Beaver vessels can be a hard sell to the finance department, as the costs can be quite high and there might be questions about the willingness from customers to pay for it. After all, at the moment, many customers are not actively engaged with Royal IHC for maintenance or other services. A reason for going ahead with the application is that it does not only apply to the Beaver vessels. Its use can be extended to all vessels created by Royal IHC as long as the underlying data is documented and kept up to date. Something that is possible with the current transition to a new ERP system. A maintenance manager also explained that even when confronted with the potential high upfront costs, if it is a service that will benefit the customer, it is worth it to pursue, otherwise our competitors will do it instead. This initiative is the responsibility of the digitization part of Royal IHC, however they might find strong allies in the maintenance part of the standard modular vessels part of Royal IHC, since the application would add a lot of value there.

9.5.3 Research feasibility and applicability of up-time based contracts

This concept has been successfully implemented in multiple industries, for example the propulsion of planes. Currently Royal IHC focuses on selling the initial Beaver as a product and provides after sales at request of the customer. The improved service design from this thesis takes it a step closer towards servitization by becoming more proactive in the maintenance needs of the assets. Up-time based contract take it to another level of service. Where the service of dredging production is sold instead of the asset itself. The key performance indicators for up-time based contract are production, up-time and vessel availability.

There is a market for Royal IHC in which this concept makes sense. As a Royal IHC installed base specialist mentioned, some indicators can be found in the mining industry. Reaching a certain production is often the most important metric. This is interesting for Royal IHC because mining companies often do not posses the experience of operating and maintaining a dredging vessel (Beaver specialist). This creates an environment where it makes sense for both parties to engage in an up-time based contract. Royal IHC maintains the vessel and makes sure that a sufficient supply chain exists, and the mining company can be assured that their production needs are satisfied (Beaver specialist).

Royal IHC has one project that seems to outperform the signed contract based on up-time. In Jordan, a fleet of Beaver vessels has been delivered with such a contract. Specifically, 75% up-time was agreed upon. Royal IHC has been able to outperform this number by quite a lot, managing to acquire a 92% up-time (Planned maintenance systems engineer). This indicates that when the opportunity arises, Royal IHC can make such a contract work for the customer, by delivering on the agreed upon contract.

It should be noted that there are quite a few challenges and limitations towards implementation on a larger scale. First of all, contractual agreements specified penalties for under performing, while not mentioning bonuses for over performing. Looking back, this is a missed opportunity because of the results the project has. Secondly, the fact that a high up-time is reached does not mean that the project for Royal IHC was profitable. Other limitations could be that this service would become expensive for customers that only operate a single vessel or a very small fleet (Maintenance manager, personal communication). This is a lesson that was learned from the Jordan project, where due to the bigger size of the fleet, maintenance programs and supply chains were easier to set up.

Further research could indicate if such a concept would work for the standard dredging vessels that Royal IHC is producing at the moment. However, it would be possible that it would take a considerable amount of resources. A team that works on this is the first step, it should contain people from the most important departments that are involved. It could also be an idea to attract experts that have already worked with such a structure and are able to find a way to implement it at Royal IHC.

9.5.4 Implementing a customer feedback loop

In order to take customer feedback in account and use it to improve the service, a questionnaire has been created. Currently this questionnaire has been distributed to 15 owners of Beaver vessels in order to gain insights in their perception of the service provide by Royal IHC, the performance of the vessel, and other feedback they might have. The results of this project are not yet received, therefore conclusions cannot be taken yet. However, this initial feedback questionnaire can provide important information to Royal IHC from the experiences from our customers. It could prove to be useful to send out these types of questionnaires on a more regular basis, in order to track customer satisfaction and reaction to certain changes in service. Customers provide a point of view that may be harder to explain for people within Royal IHC, since customers have their own environmental factors that determine how certain processes impact them. That is a reason why this information can be quite useful as feedback on current processes and how our customers view them.

The complete questionnaire is added to appendix B. The goal of the questionnaire is to receive quantitative data on how customers rate the services provided by Royal IHC. Additionally, each question also has a second part where customers can provide addition feedback that is not bound to the leading type of question beforehand. They can use this space to indicate other issues they encounter with the service. It would be wise if this was done by the person that is responsible for keeping in touch with all customers that have vessels that are in the installed base. Since this person already is in contact with many of these companies and has the ability to send out these questionnaires with some sort of regularity.

9.5.5 Applying a servitization design to different standard products

There are possibilities for Royal IHC to use this servitization structure on other products. Currently there is a push to create a standard vessel under the name "Easydredge". While the vessel is larger and more complex than a Beaver, the intention is to create a standard product, similar to how Beaver vessels are standard.

The advantage of implementing a servitization design at this point of the development would be that there is still enough opportunity to design around it. Compare this to the Beaver product where there is already is large installed base, with many different types of vessels all of whom will have different maintenance needs. Designing the standard vessel with servitization in mind can create more efficient processes, compared to implementing it after being locked-in to a certain standard.

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10 Academic reflection

This project has been quite the journey personally. It provided the opportunity to combine subjects that are within both my background as well as interest. During the bachelor, extensive knowledge of vessels and their technical systems were introduced. As well as theoretical courses on waves and their multidimensional properties. Combine this with the fact that during the bachelor, I have worked part time at Royal IHC as junior engineer.

For the masters degree, there was a wish to become a more complete engineer that does not only have extensive technical and theoretical knowledge, but understands the business side as well. The Management of Technology (MOT) masters program allowed me to learn about finance, law, macro-economics and innovation management. Connecting customers to technical solutions by being the link that can both interpret the technical side, and translate it towards customers into a solid business case. Also, being able to analyse internal- and external processes and find opportunities within them is something that has been learned during the masters program. This whole package should provide the tools to become a complete engineer that actively tries to think beyond just the solution, but gives thought to implications, adaptability and additional ways to capture value.

This project has combined the maritime sector with the insights provided during the masters program. Being able to combine an interest in the dredging industry with a project that aims to capture value from servitization has been an amazing opportunity. For example, there was interaction with many different stakeholders, of which some had different ideas or goals that had to be managed. During the masters program, stakeholder management has been one of the important topics during multiple courses. Executing this thesis in an environment where this stakeholder management had to be done provided additional insights and experiences. This added upon the knowledge gathered during the masters program and enriched the understanding of the subject with more subtle details.

During this project, many lessons have been learned. For example it turned out to be exiting to be in a high tech environment and work on innovative products. While also being able to understand and critically look at the underlying processes that existed around these products. This analytic mindset and being able to step outside the current process to take a proper look are aspects that this masters program has strengthened.

This thesis project has also shown aspects to critically reflect upon. Time management is not only done on a personal level, it involves all stakeholders. At times it proved difficult to properly set up meetings with all supervisors available due to their busy schedules. This should have been obvious from the start, but it turned out to give some delay in the process as a whole due to some meetings being pushed forward.

Another valuable lesson has been learned in the way feedback has been received and implemented. This thesis project has received feedback from many different stakeholders, each one wanting attention to different aspect or broader scoping. It has been difficult to include every bit of feedback due to the time and information limitation. This is a lesson that will result in defining a more detailed scoping in the future, in order to have clearer objectives and less scoping related issues.

I want to recognize the part that the TU Delft has played in making me the engineer that I am, throughout both the bachelor and masters program. Both my university supervisors have contributed with important feedback and suggestions, for which I want to extend my gratitude. Last but not least, I want to thank Royal IHC, and Joost Haagsma specifically, for providing the

opportunity to finish my masters program in a business environment in order to prepare me for my future career.

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A Appendix A: Operating principles

This section functions as a background in the product itself, the Beaver vessel. While the operating principles or the details about the vessel are not necessarily required to understand the service program that is designed to keep them running, it can give a feel of the product and the environment in which they operate.

Operating movement

The mechanism that Beaver vessels use for their operation can be found in the 2 black poles on the back of the ship, see figure 44. These so called spud poles can be individually lowered into the ground, this gives the vessel an anchor point on which it can rotate. They use that rotation to dredge in a cone-like shape by lowering the cutter head. Cutter head is the term for the end of the beam on the front of the vessel. The red tip, as seen in figure 37 in the appendix, will rotate and collect the material on the bottom of the water, the depth can be regulated by extending the cables. This is done by using winches, seen in figure 46 in the appendix, that hold the beam in place. Once enough material has been removed, the vessel can use a bit of the rotation and lower the second spud pole and hoist the pole that initially functioned as anchor. The new cone that is created will have some overlap with the initial area of operation, but continuing this pattern allows for movement and therefore the ability to dredge specific areas. The pattern that is created this way, is seen in figures 42 and 43. In the first figure the view of multiple runs is shown and how it can be used to dredge an area. Whereas the second figure shows a closer look at the pattern a Beaver creates during operation.

Figure 42: Aerial view of an operating Beaver

The rotation of the vessel around the spud poles can be done in two ways. The first way is by using a Delta Multi Craft(DMC), one can be seen on the left in figure 48 in the appendix. This support vessel can place 2 anchors, both 5 to 10 meter away from the center and on opposite sides of the vessel, at the very front of the Beaver. The Beaver uses a winch to alternate movement to both anchors to create the side to side movement used for its dredging operation.

The second way is with the help of anchor beams, this is an extra option that is purchasable for all Beaver models. As seen in figure 47 in the appendix, the white beams that originate from the front of the vessel and rise diagonally towards the operator room are the anchor beams. They

Figure 43: Closer aerial look of a Beaver 65 in operation

are on both sides of the vessel and can swing away from the vessel, releasing an anchor 5 to 10 meters away from the center of the vessel. A winch then allows the Beaver to hoist itself towards said anchor. It alternates use of the anchors on opposite sides to create a side to side movement useful for dredging.

When in operation, the vessel dredges soil from the bottom and that soil is being transported to shore. The soil is pumped to the back of the vessel through the white pipe. The pipe ends at the back of the vessel, this is where a floating flexible pipeline can be connected. This way, the soil can be transported to the location of choice. In case of operation further away from the shore, the vessels pump is not strong enough to transport the soil all the way to the shore. In this case a floating booster station can be used to bridge the distance and create extra pumping power. This can be seen in picture 48 in the appendix, the Beaver is connected to the booster, which transports the soil to the shore. The distance a vessel can go from the shore is restricted by the amount of flow going trough the pipe. The general rule is that with higher flow, more volume per minute, a shorter distance to the shore can be bridged.

Figure 44: Beaver 40 in operational conditions

Figure 46: Winches on a Beaver

Figure 45: Cutterhead on a Beaver 45

Figure 47: Beaver 65 with anchor beams

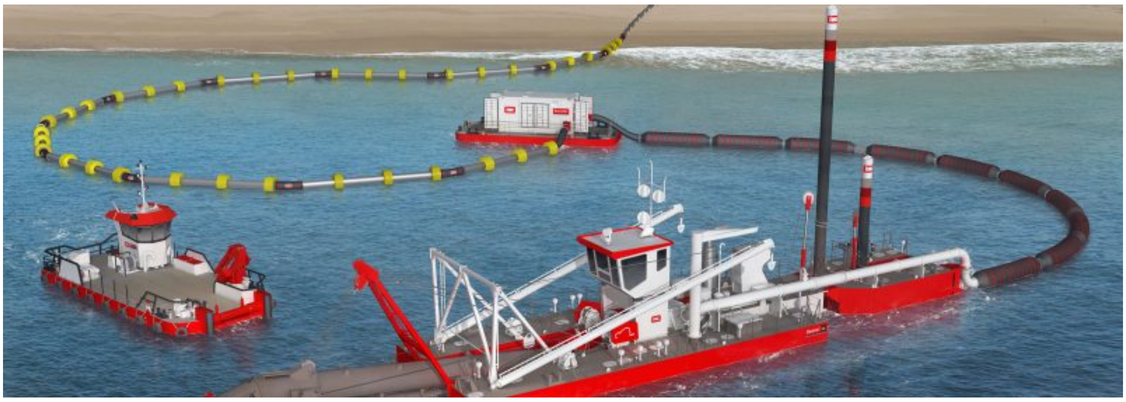

Figure 48: Beaver 65 With a booster

B Appendix B: Questionnaire

Dear customer, as Royal IHC we always strive to improve our products and service. We would like to ask you to fill the following questionnaire, afterwards we can use the feedback to make the service process a better experience.

1. I am satisfied with the services offered by Royal IHC

Very unsatisfied | Unsatisfied | Neutral | Satisfied | Very satisfied

2.
   a. Why?

3. The initial sales package was sufficient to start dredging without issues

Very unsatisfied | Unsatisfied | Neutral | Satisfied | Very satisfied

   a. What issues did you have?

4. We bought the standard spare part package; if not, go to question 5

Yes No

a. We were satisfied with the quality of the package

Very unsatisfied — Unsatisfied — Neutral — Satisfied — Very satisfied

b. The package reflects the basic maintenance needs of the vessel in the first year

Yes No

c. What, if any, parts of the package are redundant?

d. Were there any parts that should be included in the future, or in higher quantity?

2

Royal IHC

	Yes	No
5. The initial training was enough to be able to operate the vessel efficiently	◯	◯
a. We did additional training	◯	◯
b. We have been informed about DAS (Dredging advisory services)	◯	◯
c. We used DAS to be able to operate more efficiently	◯	◯

	Yes	No
6. We would consider buying a standard maintenance package that supplies all the planned maintenance articles in time.	◯	◯

a. Why?

	Yes	No
7. We would consider expanding the partnership with Royal IHC in order to better understand and plan the wear on critical parts	◯	◯

a. How would you like Royal IHC to communicate this?

	Yes	No
8. We would appreciate Royal IHC to have more of a proactive attitude in providing service	◯	◯

a. What aspects of the service could be initiated more from Royal IHC?

3