A framework towards forward cooperation in the product life cycle of dredging equipment
Preface

This thesis is written by Menno van Oeveren in order to complete the Master Construction Management & Engineering on the faculty of Civil Engineering at the Delft University of Technology. The main topic of the thesis is forward cooperation and one of the methods used to support the research a case study is executed at the dredging equipment supplier; Royal IHC.

Before studying at the Delft University of Technology I completed two other studies. The first was an Intermediate Vocational Education (MBO) Civil Engineering in Utrecht. The second was a Bachelor’s degree at the Hogeschool Utrecht in Civil Engineering. At both studies I had to complete an internship. For the first internship at, I worked at Strukton at the maintenance service team of the Betuwe Rail Route. For the second I participated in an internship abroad in Bahrain at the dredging company Boskalis.

With my personal background in civil engineering combined with the master Construction Management & Engineering, I approached this master thesis on forward cooperation with the aim to realise more cooperation between the client and contractor (chain cooperation) in the dredging sector. The challenge in this research is to apply the gained knowledge and mind-set from the civil engineering, supported by literature and a case study, into the maritime engineering.

This thesis report is written with the support of Royal IHC who allowed me to scan the entire IHC Beaver product line and helped me focus my attention. The IHC Beaver is the product that is used for the case study of this research. Therefor I would like to thank all the people at Royal IHC.

A professional group who supported me with the formation of the graduation process is the team of supervisors: Ernst, Rob, Jeroen, Joppe & Christiaan. I would like to thank the complete team of supervisors who helped me by being critical at the right moments.

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Abstract

The Dutch shipbuilding industry has a real competitive force in building complex, specialized and multipurpose vessels (Rabobank, 2014). However, the Dutch maritime sector has to deal with strongly growing competition worldwide. For the dredging sector this implies the need to innovate in order to remain competitive. This research focuses on the strategy of vertical forward cooperation to do so; the supplier will move into the maintenance aspects of dredging equipment, benefiting both the client and the supplier by expanding their services. This led to the research question of how a supplier of dredging equipment can achieve forward cooperation in the product life cycle. As a case study the company of Royal IHC is used for this research, in specific the product type of the IHC Beaver dredger is discussed. The research is divided into six parts; (i) a literature study; where the possible strategies for the forward cooperation are studied; a case study, where the (ii) IST (current) situation and the (iii) SOLL (ideal) situation are defined according to the current situation at IHC and a benchmark study. A system characterization for warranty cost analysis by D.N.P. Murthy and W.R. Blischke (2006) that describes how warranty policy, product reliability and product usage ultimately influence the warranty costs is used to structure these situations. Then a GAP analysis follows (iv) where the IST and SOLL are compared. This leads to the (v) fifth part of the research: the framework on how to achieve forward cooperation, which is supported with a model. Finally (vi) the conclusions and recommendations are given.

Firstly the current situation (IST) is researched in which the IHC Beaver is provided with one-year warranty at sale. Two important groups of stakeholders are the clients and the sub-suppliers. For the procurement of parts the role of the sub-suppliers is essential because they deliver over 60% of the parts of the Beaver dredger. How agreements are made with sub-suppliers on the warranty period of the supplied parts is therefore essential when IHC has the intention to apply forward cooperation in the future.

After the IST situation the ideal situation (SOLL) is defined. Forward cooperation can be achieved with different strategies; with the properties of the dredging market and the intention to achieve forward cooperation in the product life cycle of a standard industrial product, extended warranty has the best characteristics. Compared to the IST situation with base-warranty it is concluded that several uncertainties arise when extending the warranty with 5 years. The result of these uncertainties is that the usage and the reliability of the product cannot be predicted. This is a high risk for the supplier that will be translated in high warranty costs. In the perfect SOLL situation however most of the variables will become fixed, known or manageable.

Resulting from the GAP analysis several actions that influence the warranty costs for the supplier are summarized; develop a new warranty policy, conduct a research into the product reliability and develop a method to control the product usage to reduce the risk of intensive or improper use.

To implement forward cooperation this is what needs to be done; develop a structure where the variables ‘product reliability’ and ‘product usage’ determine the warranty costs and where the ‘warranty policy’ is the last variable to define the definitive ‘warranty costs’. Thereby the ‘warranty policy’ should also influence the ‘product usage’.

With the knowledge of the literature and the case study the following changes are made to the original model of D.N.P. Murthy and W.R. Blischke (2006) to create the eventual framework; (i) the supplier is now considered an integrator; (ii) cooperation with the sub-suppliers (backwards cooperation) is included; (iii) the warranty policies control the warranty costs by in- or excluding parts, non- or renewing warranty and a possible decrease in the coverage of warranty costs for the integrator over time; (iv) the product usage is influenced by the warranty policy so that the usage risks are (more) controlled by the integrator.

In the framework in figure 1 the warranty costs are completely dependent of the product performance, which in turn is determined by the product reliability and the product usage. To make a reliable estimation of the covered warranty costs it is of great importance that both the product reliability and the product usage are known. Furthermore the framework shows that the supplier of dredging equipment can rather be seen as an ‘integrator’ that relies on the products of sub-suppliers, therefore the supplier of dredging equipment needs to apply backward cooperation to achieve forward integration. To be able to influence the warranty costs the supplier of dredging equipment needs to offer several warranty policies that suit the product usage profile of the client. By providing different options the supplier is able to reduce the financial risks and the expected warranty costs.
Before the supplier of dredging equipment is able to offer the extended warranty, it is highly recommended to take these actions that will form the basis for the extended warranty service: (1) start logging data on product usage and product reliability; (2) cooperate and negotiate with the sub-suppliers; (3) investigate the failure mode of all parts and systems; (4) determine the warranty cost (modelling); (5) define the warranty policies and apply these to determine the covered warranty costs. Only when these actions are undertaken extended warranty can be successfully implemented by the supplier of dredging equipment.

*Figure 1: The framework for extended warranty*
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1. Research context

1.1 Introduction to the research

The Netherlands has a good position in the global maritime sector. The ports in the Netherlands have global importance for the handling and processing of goods. Dutch shipping companies have a large share in the processing of goods to the rest of Europe, both at sea and on inland waterways. Also the national maritime service companies perform maintenance of national ports and waterways. Thanks to the international use of the Dutch harbours the shipbuilding sector does business in the repair and building of ships with international clients. The maritime sector is one of the major industries in the Netherlands, which can be divided into different sectors: shipping, shipbuilding, offshore, inland shipping, dredging, ports, Navy, fishing, maritime services, water sports industry and marine equipment supply.

In order to understand in what scope this research is defined a three-layer structure represents the scope of this research. Starting from the general maritime engineering sector the scope of the research is further refined to the dredging engineering market and eventually to dredging equipment more specifically. This is visualized in figure 2.

Figure 2: Three-layer overview of the research scope

1.2.1 Maritime engineering sector

Market developments in the maritime industry

The Dutch shipbuilding industry is a strong industry in building complex, specialized and multipurpose vessels (Rabobank, 2014). However, the Dutch maritime sector has to deal with a strongly growing competition from the rest of the world, in particularly from the Asian; China, South Korea and Japan. In these countries is the national government is an important partner of the shipyards (Daling, 2015).

In addition, there is a global overcapacity in the number of shipyards. In an interview about market conditions in the maritime industry in the Netherlands Bram Roelse (CEO - Royal IHC) said: “What does not help is the overcapacity in the shipbuilding industry worldwide. The competition is tough. When the regular order flow was tightening, many shipbuilders have searched for more lucrative niches and found in the dredging and offshore industry. But the offshore industry comes to rest and the dredging industry is showing marginal growth” (Daling & Lalkens, 2015).

The Dutch maritime industry has such a strong position in the world because of the entrepreneurial and innovative capacity of the industry. General innovations, like new ideas, devices or processes, are important for a company to be able to maintain the competitive advantage. Innovation for the maritime sector may also consist of the application of technologies from other sectors and especially the integration of already developed and commercialized technologies (Aa et al., 2014, p. 122).
Concluding; the following two developments are applicable to the Dutch market of maritime shipbuilding:

- Overcapacity in the global market;
- Increasing competition from abroad.

Those two market developments imply changes for the clients as well for the supplier. The clients will have more options when choosing suppliers and because of the increasing competition the client can compel lower prices. For the existing suppliers it is therefore of utmost importance that they strengthen their client relations.

### 1.2.2 Dredging market

From the different markets within the maritime engineering sector the dredging market is the focus of this research. Since the first dredgers were built in the Netherlands and nowadays the Dutch shipbuilders of dredging equipment still own more than 50% of the new built dredgers worldwide, researching this specific market from the position of one of these Dutch dredging builders is very relevant (Aa et al., 2014).

**Characteristics of the dredging market**

This dredging industry is traditionally divided into three sectors:

- Capital dredging; e.g. the construction of new ports and waterways, and to prepare the seabed for offshore installations;
- Land reclamation; the artificial construction of land;
- Maintenance dredging; maintaining waterways and ports.

Nowadays there is also an increasing market for the mining industry, which could be considered a fourth category. The mining of minerals becomes more difficult and therefore larger equipment is required for which the dredging equipment is used. The dredging sector can thus be divided four sectors. Dredging equipment is built for clients all around the world; the chance that the equipment will remain here or work in the Netherlands is quite small. The equipment is mostly used in civil engineering projects in the Middle East, Asia & China. The purpose of the dredging equipment is to transport (produce) sand or other material by hydraulic transport. Dredging equipment is a capital-intensive product (good) with a long life expectation, this is why the rate of circulation is low. Within the dredging equipment there are mainly three different types; (i) Mechanical dredgers, (ii) Cutter Suction Dredgers (CSD) and (iii) Trailing Suction Hopper Dredgers (TSHD), this research will focus on the CSD as will be explained in chapter 2.1.

Worldwide many different types of CSD are in operation, most cutter suction dredgers are stationary dredgers that are not self-propelled, only the largest ones are self-propelled. In the middle and small range of CDS different types are available at different suppliers. The building of a CSD requires craftsmanship and is a complex process; this is why the process is standardized wherever possible but due to the differing ways of operation and the varying areas of application all cutter suction dredgers vary from each other; making each one is unique. To give an estimation of scale; the two renowned Dutch shipbuilders build one or two self-propelled cutter suction dredgers and between 10 to 20 non self-propelled cutter suction dredgers a year. The following properties are typical for standard cutter suction dredging equipment and describe the characteristics;

- High acquisition price;
- Acting worldwide;
- Moving, not committed to one place;
- Mechanically equipment designed for hydraulic transport;
- Low rate of circulation;
- Limited regulations;
- Different customer profiles.

These characteristics are useful for the benchmarking and comparison with theories and other sectors. The market of standard-built dredging equipment can be approached as a *push market* from the supplier to the client.
**Niche market**

The dredging market is a demarcated market in the maritime sector with specific characteristics. A wide variety of definitions exist related to niche markets, the characteristics of the dredging market match with the definition of a niche market given by Kotler. Kotler defines a niche as ‘a more narrowly defined group seeking a distinctive mix of benefits’ (Kotler & Keller, 2003, p. 280). Kotler stated that niche markets are usually identified by dividing a segment into sub segments and that the key issue in niche marketing is specialization. Kotler presents niche markets as having the following characteristics:

1. The customers in the niche have a distinct set of needs;
2. The customers will pay a premium price to the firm that best satisfies their needs;
3. The niche is not likely to attract other competitors;
4. The niche gains certain economies through specialization;
5. The niche has size, profit, and growth potential.

The characteristics stated by Kotler are applicable to the dredging market. Notable is the third characteristic that assumes it is not likely to attract other competitors into the niche market.

The reports made by the Maritime Monitor (2014) and the Rabobank (2014) on market developments in the maritime sector conclude that the shipbuilding industry is under pressure of an overcapacity of shipbuilders and a decreasing demand for newly built ships because of the economic crisis. This could explain why other shipbuilders switch markets and (partly) move into the building of dredging equipment. Until now the dredging market is approached from the position of the supplier. For the supplier of dredging equipment the market is defined as a niche market. From the perspective of the client or the user of the product, the market has different characteristics. In the market of dredging companies there are several actors who are able to execute the same kind of projects. The commitment of dredging equipment is diverse; from general deployment to specific deployment. On the general (more easy) deployment of dredging equipment there is a lot of competition. The equipment also has to compete with conventional equipment, like excavators on a barge. The dredging equipment is often part of a major project, within the projects the equipment fulfills an important role but there are several other aspects that will count. However to this research it is most important to know the market can be defined as a niche market from the perspective of the supplier.

1.2.3 Capital goods in the dredging market

**Capital goods**

Dredging equipment is, compared to other regular ships in the maritime sector, designed and built as equipment to make production in forms of transporting soil and not to sail from A to B. There are different kinds of dredgers; they differ in their way of digging, either hydraulically or mechanically. Both ways of dredging require a ship with specific components that are integrated to a system to produce a quantity of soil.

Dredging equipment is mostly used in civil engineering projects where its purpose is to make production as planned. Dredging equipment is defined as: ‘a unique piece of equipment which can dig, transport and dump a certain amount of underwater laying soil in a certain time’ (Vlasblom, 2003). This brief explanation of dredging equipment is similar to the more abstract definition of capital goods. There are many different meanings associated to capital goods. Veldman & Alblas (2012) define capital goods in relation to the lifecycle. ‘Capital goods are generally considered as one-of-a-kind, capital-intensive products that consist of many components. They are often used as manufacturing systems or services themselves’ (Veldman & Alblas, 2012). Examples include marine ships, oilrigs, baggage handling systems and roller coaster equipment. Their production is often organized in projects, with several parties cooperating in consortia. A capital good lifecycle typically consists of tendering, engineering and procurement, manufacturing, commissioning, maintenance and decommissioning.

The dredging market is a specific industry within the maritime sector with its own characteristics. Combining the two definitions explained in this paragraph concludes that dredging equipment can be generally approached as a capital good in a niche market.

This research will be conducted in the context of dredging equipment within the maritime industry as explained in this research scope.
2. Problem analysis

2.1 Dredging equipment

2.1.1 Life cycle phases

Since dredging equipment is a product of high value (as stated before it is a capital good) the theory of the product life cycle is applicable. In fact the dredging equipment lifecycle can be divided into the five phases of the product life cycle; (i) Needs & Requirement, (ii) Design, (iii) Production, (iv) Exploitation and (v) Disposal (Kumar, Crocker, & Knezevic, 2000).

In the first phase, needs and requirements are defined based on feedback from the market, technical possibilities & innovations and on the requirements from the client. With this set of requirements the design can be made and after approval the production can begin. Then, after delivery the exploitation phase will start, this phase consists of maintenance & operations and generally lasts for a period of 10 to 30 years. Finally, at the end of the functional lifetime the product will be disposed, recycled, redesigned and/or upgraded.

2.1.2 Life cycle costs

The decision for the investment in a capital good by the asset owner is partly based on the life cycle costs of the product. Stavenuiter (2002) approaches the cost of a Naval vessel by using the Life Cycle Costs Analysis. The predicted total of life cycle costs is determined by combining all the relevant cost elements associated with the costs incurred for the acquisition, operations, maintenance and disposal of the ship. These costs reflect the total cost of ownership. Figure 4 illustrates the fact that a major part of the total costs of a Naval Vessel are maintenance costs rather than acquisition costs. For a regular cargo ship or a large bulk carrier the maintenance costs are a large part of the total life cycle costs. For dredging equipment the maintenance and operation costs are even higher because of the high fuel consumption and the consumption of wear & tear parts. Stavenuiter (2002) states ‘this is why it is utmost important that every effort will be made during the acquisition process to design a system that optimizes the total life time cost rather than acquisition costs’ (Stavenuiter, 2002).
In figure 4, the costs of a Naval vessel are stretched over the entire life cycle. When comparing the investment costs and the life cycle costs it turns out that they are practically even. So regarding the financial competitiveness, the costs of the maintenance and operation phase are evenly or more important as the acquisition phase.

2.1.3 Market developments regarding life cycle phases

By analysing the life cycle of dredging equipment, it is evident that there is a clear distinction (separation) between the asset owner and the supplier of the ship. In other sectors, like the civil engineering sector, the trend is that the contractor is becoming more responsible for the maintenance phase and therefore stimulated to deliver an optimised product with low life cycle costs (Noordhuis & Vrijhoef, 2011). This general development could be one of the possible ways for the suppliers in the dredging sector to expand their market share.

Another benefit of the involvement of the supplier in the maintenance phase is the feedback loop out of the operation phase, which helps to improve the future design. This feedback loop is currently incomplete in the dredging sector because of the separation between supplier and asset owner. By improving the feedback loop, the dredging suppliers could improve their design and reduce the total cost of ownership of the capital goods they produce, and thereby gain or improve competitive advantage.

2.2 Market conditions

The dredging sector is a specific industry within the maritime sector that needs to cope with two market conditions; (i) the overcapacity of the maritime ship building market and (ii) the increase of competition from low-wage countries. For one dredging supplier to keep their competitive advantage within this market, it is necessary to adjust their strategy. If to remain competitive, the dredging supplier needs to improve their value proposition in order to remain secure of their market position in the future.

From the life cycle phases, it is seen that there currently is a clear separation between the supplier and the client. Once the capital good is bought after the building phase, the capital good is handed over to the client and there is no real cooperation from there on between the supplier and the client. This provides huge chance for improvement, the cooperation needs to enhance the value proposition of the product with professional services and therefore a high involvement between the supplier and the client is essential.

What kind of strategies can be explored for the enhancement of the cooperation between the client and supplier will be explored in the next paragraph.

2.3 Exploring a strategy

2.3.1 Forward vertical integration

When looking for a way to deal with the separation between the supplier and the client, the overcapacity in the global shipping market has to be taken into account. The solution will not be found in the direction of market extension because of the overcapacity in the global shipping market, so it has to be found in the niche market itself. In the previous paragraph, the life cycle of dredging equipment showed that there is a possible opportunity for the supplier in the operation and maintenance phase.
A method frequently used in microeconomics and strategic management when a company wants to expand in the supply chain, is vertical & horizontal integration. Because the separation is between the two phases and the vertical integration is already applied in the dredging sector, the vertical & horizontal integration are converted to the life cycle.

Figure 5 gives a visualisation of forward and backward integration applied on the life cycle. There are two different integration types; vertical and horizontal.

- Vertical integration is when the company expands its operation to incorporate more and more aspects of the life cycle. For example; a business that originally only designs products but now sets up their own production line and sometimes takes over an existing production company (Jurevicius, 2013).

- Horizontal integration is the merger of companies at the same stage of the life cycle in the same or different industries. When the products of both companies are similar, it is a merger of competitors (Jurevicius, 2013).

Forward and backward integration give the direction of the integration over the horizontal or vertical axis.

Since the maritime industry is subjected to overcapacity it is not obvious to extend on the horizontal axis because of the competition, so that excludes horizontal integration. The competitors are also looking for opportunities in the dredging market, which is why it is important for existing dredging suppliers to improve their competitive advantage. An option to improve the competitive advantage is to apply vertical forward integration.

2.3.2 Forward vertical cooperation
Forward integration provides two options; either to set up a new business (division) or to take over an existing company in that particular business. These two options both intend to start/take over a legal entity including all the risks and opportunities. When relating this to the life cycle, forward integration would intent that the supplier moves into the operation business. Which is not preferable since the supplier will become a competitor of its own clients. The supplier is interested in the maintenance aspects of dredging equipment and not to operate and own the equipment. So the supplier is looking for a form of collaboration with the client that would benefit both, therefore forward cooperation is a more suitable strategy.
The term *cooperation* can be defined in different ways, it will be specified by the use of some criteria. In the criterion of a coordination system, cooperation can be differentiated from market and hierarchy. The coordination of a system in markets is the price mechanism, in hierarchies it is instruction and in cooperation it is negotiation (Seuring & Goldbach, 2002).

To continue in the types of integration like mentioned in the previous paragraph, the collaboration between partners of different levels in the supplier chain is called vertical cooperation. The horizontal cooperation is complementary to this type. In this case, the partners on the same level of the supplier chain collaborate.

To improve the competitive advantage the strategy of vertical forward integration will be replaced by *vertical forward cooperation*. There are several possibilities to achieve the forward cooperation: (i) base warranty, (ii) extended warranty, (iii) Service Level Agreements (SLA), (iv) service contracts and (v) integrated contracts. For this research the focus will be on the forms of forward cooperation. The definitions and the differences between the different levels of service will be explained in the literature chapter.

### 2.3.3 Economy of skill

Now that the theory is discussed the next step is to explore a possible strategy on how to achieve forward cooperation. One way of shaping a strategy to get more involved in the operation and maintenance phase of the client is written by Auguste, Harmon and Pandit (2006). They wrote an article with the title ‘the right service strategy for product companies’ based on practical examples that designed a strategy for product companies. Generally these are product companies in the professional or embedded service sector lacking a strategy to align their businesses towards a service. Many organisations stumble by pursuing scale-based business strategies in skill-based service markets or vice versa.

To succeed in professional or embedded services, the theory of Auguste et al. (2006) reflects on strategic intent and its source of advantage, see figure 6. To make the first distinction on the dredging equipment it is necessary to determine if the business is based on economies of scale or skill. *Economies of scale* involve high volumes, low variable costs and high utilization of fixed assets. Businesses with economies of scale benefit from standardized and automatized process. *Economies of skill* create mainly value by identifying, developing and replacing scarce capabilities or developing process innovations. The skill can be seen as detailed knowledge of a product, as well as the experience and tools to fix problems and reduce the customer’s total cost of ownership (Auguste et al., 2006, p. 45). Relating this distinction to the standard-built cutter suction dredger the business is mostly based on economies of skill due to the detailed knowledge of the product, the low production rate and the different characteristics of each dredger due to varying purposes in operation. With this first observation, the vertical axe of figure 6, the source of competitive advantage can be established in order to apply this theory.
The horizontal axe makes the distinction based on the strategic intention of the business. The first strategy is a common used strategy to *protect or enhance the product*. The aim is to ensure high quality product support and to strengthen the relationship with the customer. The strategy to *expand on independent services* entails difficult issues of integration and separation between product sales (the company's core-business) and the sale of value added services. As a remark it is given that companies are tempted to see the service business as a growth platform. But applying the embedded services to expand as an independent business is challenging and requires a distinct strategy and organisation (Auguste et al., 2006, p. 43). The strategy applicable on this research will be to *protect and enhance the product*, the standard-built dredging equipment.

With the obtained results it is possible to use the table in Figure 6. The findings are originally stated for product companies who are designing services, although shipbuilding revolves around bigger products than described in the paper by Auguste et al. (2006), the findings from these table are to some extent still relevant for the shipbuilding industry. The results or advises are divided in four subjects and list:

- **Pricing**: Optimize the life cycle profits with embedded services;
- **Sales**: Integrate solutions to reduce the total cost of ownership for the product;
- **Delivery**: Design products to be serviced;
- **Organization**: Measure life cycle profits, revenues and productivity.

When relating these results to the standard-built dredging equipment it is evident that the services offered should strengthen the life cycle of the product.
3. Problem definition

3.1 Problem definition
Concluding from the previous chapter the following problem definition can be defined. The Dutch dredging equipment suppliers are coping with competition from other countries. In order to stay ahead of the competition the dredging equipment suppliers need to expand their services. A way of expanding their services is by applying forward cooperation. There are several ways to apply forward cooperation but it is unknown which way is suited for the dredging equipment suppliers.

3.2 Research question
Resulting from the problem analysis the main research question has been formulated below.

“How can a supplier of dredging equipment achieve forward cooperation in the product life cycle?”

To be able to answer to the main question the research is divided into different sub questions. By answering all the sub questions it is possible to give an answer to the main research question.

Sub-questions:
1. What are the characteristics of (base) warranty and how is (base) warranty currently defined? (IST)
   - Literature
   - Single case IHC

2. What are possible options to achieve forward cooperation and how can these (contract) forms be defined? (SOLL)
   - Literature
   - Single case study IHC
   - Benchmarking

3. What is the difference between (base) warranty and the chosen form of forward cooperation? (GAP)
   - GAP-analysis for single case study

After answering these sub questions this will lead back to the main research question;

“How can a supplier of dredging equipment achieve forward cooperation in the product life cycle?”

- Framework design (evolved from single case study)
3.3 Objectives
The aim of this research is to explore the possibilities of forward cooperation for suppliers of capital goods in a niche market and to make a framework that is applicable for other suppliers in capital goods as well. In order to achieve the objective of the main research, three sub objectives are defined:

- To get insight in the lessons learned from other sectors on applying forward cooperation;
- To explore if theoretical findings from capital goods can be applied on dredging equipment;
- To get insight in the implications of applying forward cooperation on a capital good in a niche market, by performing a case study with Royal IHC.

Develop a framework
The main goal is to develop a framework that will be a structure designed to support other capital good suppliers to set up their extended service and thereby focus on minimizing the risks and maximizing the benefits.

The framework will be based both on theory and practice. The basis of the framework will be made during the analysis of the theory. The content of the theory will focus on lessons learned from the application on capital goods in other sectors and on basic theory on forward integration or cooperation. During the case study practical knowledge will be gathered and translated into the framework. In the end the theoretical and practical knowledge are combined to one framework.

3.4 Relevance

3.4.1 Theoretical relevance
The literature available on forward integration on capital goods is limited and mainly applied on products with high production quantities. According to that literature forward integration is usually applied in supply chain management. In this research forward integration is applied on the life cycle of dredging equipment and the term integration is replaced by the term cooperation because there is an intention to cooperate in the next phase of the life cycle. The findings are based on theory and supported by the case study, together they can give new insights for the currently available theory on forward integration.

There are different levels of analysis regarding the forward integration as far as known in theory opposed to the context of this research. Regarding the topic of forward integration this research further specifies the context in the following steps:

1. Forward integration in supply chain;
2. Forward integration in the product life cycle;
3. Forward integration in the life cycle of capital goods in a niche market;
4. Forward cooperation in the life cycle of capital goods in a niche market;
5. Forward cooperation for a supplier of capital goods in a niche market in the product life cycle;
6. Forward cooperation for a supplier of dredging equipment in the product life cycle;
7. How can a supplier of dredging equipment achieve forward cooperation in the product life cycle?

The goal of this research is to answer the last question (number 7). However for theoretical relevance it is interesting to translate these findings back to the more general levels of analysis.

3.4.2 Practical relevance
For the research a case study at a supplier of the dredging equipment will be performed. This case study is executed within the Dutch shipbuilding company Royal IHC.

Introduction to Royal IHC
Royal IHC is a capital goods company producing in a niche market. IHC is known as a specialist in designing & building, offshore & dredging equipment and other related equipment. In the past, various shipyards merged together and since 2005 they formed one large company to get a stronger position in the market. Royal IHC has more than 70 years of experience in building equipment for the maritime industry. During these years the company has developed several other services to support their products and their ambition is to expand more in services.
On a newly built ship IHC currently provides one year of warranty. In addition to this one-year warranty there are various other services and products offered, these products are known as after-sales. These products can be spare-parts (packages) but they can also be services like; the assistance in maintenance or giving a training session to the crew. It is important to note that IHC already has experience in offering these after-sales, since this is an important factor for the client in operations phase of the dredging equipment.

In practice the competition from foreign companies is increasing for IHC because of the overcapacity in the regular shipbuilding industry. IHC is situated in the niche market for dredging and offshore equipment and because of their established expertise and knowhow within this market it is wise not to enter a new industry, but to stick with their core value proposition. An opportunity is to extend towards the operation & maintenance phase that is in control of the asset owner (client) right now.

**Interests research for IHC**

The dredging equipment is an important tool in the dredging industry; it is the key equipment for the client or asset owner. From the perspective of the life cycle there is an opportunity for the supplier in the operation and maintenance phase and more specific to the maintenance activities. A standard one-year warranty period is applicable to newly built equipment which already creates a good starting position for further research since data about this phase is already available.

The suppliers’ aim, in this case for IHC, is to get more involved with the client during the operation phase because of the following objectives:

- **For market extension**
  The building of new products is the core business of a product company like the supplier of dredging equipment. All services are created in order to support the product. Nowadays the supplier is providing a one-year warranty period on delivered products. To extend this market, it is an opportunity to offer warranty for more or less than the current year or to offer any other kind of service contracts.

- **To stay ahead in competition**
  Due to the increasing foreign competition suppliers have to innovate their products continuously. At the moment creating increasingly sophisticated products does it. However times are changing and suppliers need to explore new ways of creating value to their client. One way to create more value for a product could be long-term services to the product. This offers the possibility or a commitment to improve the services of the company to the product to maintain this competitive advantage on the longer run.

- **For product improvement (feedback)**
  When getting more involved in the maintenance & operations phase of the customer, the feedback data will increase for the supplier. This feedback data from operations could improve the products and could provide a maintenance analysis if the data is up-to-date. The data analysis could also result into an improved design of a new product.

**Introduction in the case study within Royal IHC**

The single case study within IHC is based on the technical features of the IHC Beaver series and on conducted interviews within IHC. The IHC Beaver series is designed and developed within IHC over the years. The IHC Beaver dredger is a demountable dredger with a pipeline diameter range varying forms 260mm (IHC Beaver 30) up to 650mm (IHC Beaver 65). The IHC Beaver dredgers are introduced in 1963 and continuously updated. These dredgers are built on stock, to ensure fast delivery time to a client. Although the dredger is built by IHC external suppliers of systems and parts are required to complete the IHC Beaver dredger.

Within the IHC Beaver series the Beaver 50 is chosen for the case study in this research because of the facts that:

- The system of the Beaver 50 is similar to the system of the smaller types;
- It is driven by a single engine;
- The Beaver 50 is the dredger that is most delivered over the last years.
The Beaver 50 is the largest single engine driven dredger within the Beaver series and is a good representation of the smaller types. If required, the data from the smaller types can be used because of the similarity in the system, the difference is mainly based on size. The Beaver 65 is in size, power and system larger and more complex than the rest of the Beaver series.

Figure 7: IHC Beaver series 2015 (IHC, 2014)
3.4.3 Social relevance
Due to growing competition from abroad the building costs and sales price of dredging equipment are under pressure. If the Dutch shipbuilders lose their powerful position within this competitive market the employment of these companies will become questionable; possibly resulting in redundancies.
As a reaction against this intensifying competition the Dutch shipbuilders have to reduce their expenses by moving their production to foreign countries with lower wage and reducing building locations in the Netherlands. As a consequence of the new strategy set out by Royal IHC the company has terminated the employment of more than 480 employees and phased out a large part of the flexible workforce in 2015 (Daling & Lalkens, 2015). This has had a huge social impact for the former employees, mainly living within the nearby area of Sliedrecht and Kinderdijk.

From an economic perspective the contribution of the Dutch shipbuilders to the knowledge economy (which in the Netherlands mainly relies on technology) is something that should be supported in order to stimulate this knowledge economy in the future.

3.5 Research method
This part of the problem definition will give insight in what kind of approach will be taken, in other words which kind of research strategy to follow. With research strategy Verschuren and Doorewaard (2010) mean the coherent body of decisions concerning the way in which the research will be done.

Starting with making a set of key decisions from which a number of other decisions will follow.

The first consideration is whether the research intents to gain a broad overview (Breadth) or a thorough investigation of all the aspects of a phenomenon (Depth). This research is focused on the forward cooperation in the dredging market, which is a specialised niche market. Therefore this research aims to thoroughly investigate this phenomenon, which is considered Depth. This choice will aim for a small-scale approach and therefore the research will be conducted at a company that holds a strong position within this niche market. With their support the necessary data and insights can be accessed and further researched.

A second key decision that is related to the concerns whether or not the research prefers quantification, in which the research findings are compiled in tables, charts, numbers and calculations. Or whether the research is more a contemplative one and uses a qualitative and interpreting approach, in which the reporting is mainly verbal and contemplative.
This research depends on knowledge out of the theory and practice and will result in a method or framework. The input is mainly qualitative and most of the questions are how and why questions, this research can therefore be considered as a qualitative research.

The third key decision is related on how the research will be implemented. Is the research related to practices in the field, gathering data to make judgments based on the analysis of these data. If the research would use the existing literature or data gathered by others, it can be defined as a desk research. Otherwise the research will be categorized as an empirical research since it concerns a practical field study.
This research is actually a combination of both. In the first phases the knowledge is gained from the literature and later on it will be combined with practical experience to a new framework. So, the research will begin as a desk research (literature study) and will later on change in an empirical research (case study) (Verschuren et al., 2010).

The three key decisions mentioned above are interconnected with many other decisions and strategies. The research method is based on these key decisions and objectives; the final research design is illustrated in figure 8.
3.5.1. IST-SOLL Analysis

**Focus**
Implied by the first key decision the research will have a ‘Depth’ character. Because the timespan and resources of this research do not allow to investigate all players within the dredging market the research method requires to select a case for this study to limit the frame of the research. To be able to fully investigate the topic of forward cooperation in the life cycle of dredging equipment and gain in-depth insights it is necessary to explore the situation of a single company in the first place. Only by limiting this scope of research for the IST-SOLL analysis to one case company the requirements of the Depth research can be met.

**GAP analysis**
To be able to access valuable data and insights necessary to conduct this research it is chosen to focus on the company of IHC. Since Royal IHC is world market leader in the dredging market and is one of the key players with only few competitors it is chosen to conduct this research with their support (Usa, 2007, p. 211).

For this company the current situation (IST) and the desired future situation (SOLL) will be analysed regarding forward cooperation in the life cycle of their dredging equipment. By making a GAP analysis between these two situations it can be studied what is missing to meet the requirements of the desired situation (SOLL). Based on this GAP analysis the framework will be created.

Because of the limitation of this research to IHC and the eventual framework resulting from the above analysis it is necessary to reflect back upon the validation of this framework to the entire dredging market. As a consequence it must be considered what implications this limitation of the analysis has for the validation to the entire market of dredging equipment. This will be done at the end of the research; after the framework is introduced the validation to the entire market will be discussed in chapter 8.
4. Literature review on warranty and forward cooperation

This chapter gives all the relevant theoretical knowledge gained during the literature study. The literature study will provide the foundation to answer the main research question and will eventually contribute to the creation of the framework. This chapter is set up in the same structure as the research method. Firstly the background of the current situation (necessary to analyse the IST situation) is elaborated by explaining base warranty in a theoretical way. The second part of the literature study is an analysis of possible solutions to achieve forward cooperation in the product life cycle (necessary to explore the SOLL situation). Four different approaches are elaborated and finally compared. The possible solutions are (i) Integrated contracts, (ii) Service level agreements, (iii) Extended warranty and (iv) Maintenance service contracts.

4.1 Warranty

Within the current situation in the dredging market the relationship between the supplier and client is quite strictly separated; there is not much cooperation between them on the long term. Right now the supplier provides a one-year warranty on new dredging equipment. During this one year period the supplier and client cooperate to let the equipment function optimally. After this warranty period the cooperation is minimized to the supply of spare parts from the supplier towards the client. Other than the supplying of spare parts there is not much cooperation between the two stakeholders. With the goal to expand this cooperation by means of forward cooperation the current warranty period, the first year after selling the product, is a good starting point for further research.

In this first paragraph the definition, history, types and stakeholders involved in the process of warranty will be explained. Concluding this paragraph will answer the following question: What are the characteristics of warranty and how are they specified?

To be able to give an answer to this question a literature review is executed. The chapter will start with basic definitions and the background of warranty and will finish with the theory of D. Murthy on what the specifications for warranty are.

Categorization dredging equipment

Dredging equipment is already described in the previous chapter and will be further elaborated in a practical approach in the next chapter (IST situation). To search for definitions of warranty in the literature, the dredging equipment needs to be categorized to understand which definitions are applicable or not. It is necessary to know whether dredging equipment can be considered to be a product. One definition of a ‘product’ is the following; A product can be tangible (e.g. assemblies or processed materials), intangible (e.g., knowledge or concepts) or a combination thereof. A product can be intended or unintended (Hoyle, 2001).

The previous chapter stated dredging equipment is characterized as a capital good in a niche market. Combined with the definition above the dredging equipment can thus be considered as a (large) industrial product for which the term of product warranty can be applied.

4.1.1. Development of warranty over time

Through time the role of product warranty in the society has changed. The notion of warranty became more complex and as opposed to an exception warranty became the new standard (Sahin & Polatogu, 1998). Different theories of warranty were developed; three of these theories and time phases will be elaborated upon.

- Exploitative theory

In the early ‘50s the exploitative theory has its origins in legal literature on warranty. This theory is developed for the benefits of the manufacturer, while the consumer has only a few rights and bears the risk. The manufacturer added an additional price to the product instead of offering a service that should be provided anyway. Some buyers reasoned that if the manufacturer offered no warranty, the manufacturer did not have confidence in the product. Round 1975, the consumers were still at the mercy of manufacturers; consumer rights were not noticed, terms were couched in legal jargon, administration was confusing and ineffective and unjustified claims often resulted from consumer frustration. In the United States the Magnuson-Moss Warranty Act (1975) aimed to provide consumers with information, improve the quality of warranties and provide procedures for consumer remedies. To some degree the act succeeded but mostly it remained far
from ideal. One improvement of the act was that the warranty became a good indicator of the product reliability, which leads to the signal theory of warranty (Murthy & Blischke, 2006; Sahin & Polatogu, 1998).

**- Signal theory**

Over the years products became more complex and less easily to evaluate by the consumer. Warranties were used as indicators for the performance and reliability of the product. The product performance and the warranty terms influenced the production process of manufacturer. So a longer warranty period resulted in higher costs unless product performances were of higher quality. At this moment the ‘signal’ of warranty became part of a marketing strategy; when the manufacturer offers a better warranty than a competitor, the reliability of the product should also be better. A market study in the *Journal of Consumer Research* by Wiener (1985) concluded that for the consumer durables markets “warranties were accurate *signals* of product reliability” (Wiener, 1985). This research also found that warranty became better at signalling product reliability after the Magnuson-Moss Warranty Act (1975) than before (Murthy, 2006; Sahin & Polatogu, 1998).

**- Investment theory**

More recently, warranty has been viewed as an insurance policy and a repair contract. The buyer sees warranty as an investment that reduces the financial risk in the early product lifetime, while the manufacturers are insured against warranty claims caused by improper use. “The aim is to extend the useful life of the product by specifying the responsibilities of the manufacturer and the buyer. By specifying a repair policy, the manufacturer aims to build a long-term relationship with customers, hereby retaining their business even after the warranty period expires” (Murthy & Blischke).

Concluding on these theories warranty became an important indicator to secure the quality of a product from the manufacturer to the customer and the offering of warranty allows a manufacturer to differentiate from its competitors using it as a tool for increasing its competitive advantage. Offering better warranty terms signals better product quality and greater assurance, which could in the end lead to increased sales. The benefits for the client and for the manufacturer will be discussed later.

**Current situation**

At present, nearly everything purchased is covered by warranty, either *express* or *implied*. An *express warranty* is one whose terms are explicitly stated in writing. An *implied warranty* is a contract that is automatically in force upon purchase of a product to the supplier of the product.

The above three theories describe briefly how the concept of warranty has changed over time. These theories were all relevant developments within their historical contexts. To consider warranty as it is seen now it is necessary to relate it to the context of nowadays society. The modern industrial society is characterized by:

a) Changing technologies;

b) Strong competition between manufacturers (products become nearly identical due to common components and technologies);


**4.1.2. Defining warranty**

In the previous paragraph it is elaborated where warranty came from, but what is the right definition of warranty related to products and management strategies?

The terms warranty and guarantee are often used synonymously. The distinction is that guarantee is defined to be a pledge or assurance of something; a warranty is a particular type of guarantee, namely a guarantee concerning goods or services provided by the seller to a buyer. Therefore the term warranty is applicable to this research context.

**Definition of warranty**

Multiple definitions of the term warranty were explored, the listing of these varying definitions can be found in appendix A. For this research the most appropriate definition of *product warranty* that will be used is the following by Murthy & Blischke; ‘A warranty is a written and/or oral manufacturer’s assurance to a buyer that a product or service is or shall be as represented. It may be considered to be a contractual agreement between buyer and manufacturer (or seller) that is entered into upon sale of the product or service. The contract specifies product performance, buyer responsibilities, and what the warrantor (generally the manufacturer) will do if an item purchased fails to meet the stated performance. A warranty may be implicit or it may be explicitly stated’ (Murthy & Blischke, 2006).
Product warranty
Murthy (2006) categorizes products in four groups: (i) Consumer non-durables, (ii) Consumer durables, (iii) Industrial & commercial products and (iv) Specialized defence-related & industrial products. Murthy (2006) also divides products in two classifications: Standard products and Custom-built products. Dredging equipment can be compared with Industrial products; industrial products are characterized by a relatively small number of consumers and manufacturers. The technical complexity of such products and the mode of usage can vary considerably. The classification of products is in line with the problem definition; the dredging equipment for this research is a standard product. Combining the descriptions of Murthy will result in the category of; standard industrial products.

Warranty management
Concluding paragraph 4.1.1. on the concept of warranty over time it is noticed that warranty can also play an important role in the strategy set out by the supplier. This strategy is set out by the management of an organization and is then executed on different levels of the organization. In most businesses strategies are set out by top management and executed at lower levels of the organization. Therefore, the strategic time frame is long and decision-making needs to take into account the impact of both internal and external factors. External factors are for example the economy, competitors, legislation, etc. Internal factors are for example outcome of research and development or product improvements. Since strategy has an effect on many levels of the organization, includes many different resources and is hard to define overall it is tried to break down the strategy into smaller components in order to get a better grip on the definition of strategy. This is done according to the theory of Murthy & Blischke (2006).

Firstly this theory explains how strategies can be separated in two groups; (i) technical/operational and (ii) commercial strategies. These two strategies are divided in subcategories and explained in table 5.

<table>
<thead>
<tr>
<th>Technical/operational strategies</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical strategy</td>
<td>Outline goals, expectations and measures related to the product performance.</td>
</tr>
<tr>
<td>Design &amp; development strategy</td>
<td>Engaged with product design, development and testing in relation to reliability.</td>
</tr>
<tr>
<td>Manufacturing strategy</td>
<td>Covers the quality and cost aspects of production.</td>
</tr>
<tr>
<td>Purchasing strategy</td>
<td>Oversees the selection and quality of suppliers and associated contractual issues.</td>
</tr>
<tr>
<td>Process control strategy</td>
<td>Outlines procedures for sampling and testing, and standards for acceptance.</td>
</tr>
<tr>
<td>Process maintenance strategy</td>
<td>Describes the procedure for maintenance scheduling to reduce downtime and associated costs.</td>
</tr>
</tbody>
</table>

Table 1: Technical/operational strategies (Murthy & Blischke, 2006)

<table>
<thead>
<tr>
<th>Commercial strategies</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marketing strategy</td>
<td>Involves assessing the potential market to ascertain what product features, price, and warranty terms are in demand, and developing strategies for pricing and advertising.</td>
</tr>
<tr>
<td>Post-sale servicing strategy</td>
<td>Outlines procedures and targets for warranty terms, extended warranty issues, and repair strategies.</td>
</tr>
<tr>
<td>Service strategies</td>
<td>Provide benefits to customers and deal with customer dissatisfaction.</td>
</tr>
</tbody>
</table>

Table 2: Commercial strategies (Murthy & Blischke, 2006)

From the three theories of warranty paragraph 4.1.1. concluded that warranty had two positive effects; firstly on the product quality and secondly on the competitive advantage. Now that the strategy can be described with help of the categorization made by Murthy & Blischke (2006) in tables 5 and 6 the positive outcome of warranty can be related to the strategy components in which they are influenced. This reasoning is done by the following steps;
Following this reasoning it can be said that both the manufacturing strategy as well as the marketing strategy are influenced by warranty. Also other strategies, such as for instance the post-sale servicing strategy, are partly defined by warranty.

It can be concluded that strategic warranty management takes into account the warranty related decision problems on technical or operational and commercial strategy levels and also takes both internal and external factors into account. Operational strategies need to be developed to address the effect of manufacturing on warranty issues and is intern orientated (Murthy & Blischke, 2006).

For the case study it is important to realize which sorts of strategies are influenced by warranty. Thereby it is important to notice that it does not only affect technical or operational strategies but commercial strategy as well.

4.1.3. Options for warranty policies

Different types of warranty policy can be agreed upon based on different agreements on the dimension of warranty (one-dimensional or two-dimensional), sort of warranty (base or extended) and whether the contract is renewing or not. In the this paragraph the most important types of warranty will be elaborated and in the end summarized in table 4.

One and two-dimensional warranty

In the base warranty and in extended warranty can two types of policies can be distinguished: (i) one-dimensional and (ii) two-dimensional. Policies can be seen as the translation of the companies’ strategy for the warranty into a set of rules and regulations to execute that strategy.

One-dimensional warranty is characterized by an interval, called the warranty period, which is defined in terms of a single variable, e.g. time, age or usage. Two-dimensional warranty is characterized by a region in a two-dimensional plan, mostly one axis for the time or age and the other axis for usage. As a result, many different types of warranties, based on the shape of the warranty coverage region, may be defined.

In figure 9 three different possibilities of two-dimensional policies are shown. The first one (a) is the usual warranty region with independent limits on time and usage. The second figure (b), the warranty is favour of the buyer; a minimum coverage of time and a minimum of usage are assured for the customer. The last figure (c) is a compromise between (a) and (b), where the buyer is provided with warranty coverage of minimal time \( W_1 \) and a minimum usage \( U_1 \). The warranty is limited to a maximum time period \( W_2 \) and maximum usage \( U_2 \). For example, if a product is used intensively the minimal usage will be reached quickly but as long as the minimal time in not fulfilled the product is still under warranty, unless the maximum is reached.

Figure 9: Two-dimensional warranty regions; Usage (U) & Time (W) (Murthy & Blischke, 2006)

Sorts of warranty

The normal or base warranty is integral to the product sale and is factored into the sale price. In contrast, extended warranties are warranties that buyers can purchase by paying an additional amount, so that the item is covered for a period beyond the base warranty.
Not only the manufacturer but also third parties such as a dealer, insurance companies and credit card operators can offer extended warranty. Extended warranty is a source of additional revenue to all different businesses. Extended warranty will be elaborated more in depth the next chapter.

Renewing or non-renewing warranty
In renewing warranty the warranty period begins again after each replacement or repair. Non-renewing means that since an item is repaired or replaced, the item will not have a new warranty period, but only the time remaining in the original warranty period.

Other variations on warranty
Besides these three variation possibilities there are also other characteristics on which the warranty can differ. These are the actions of the supplier upon failure, in which it is optional to either repair or replace the parts or to make a refund.
Another variation option on the warranty is whether the warranty agreements are staged over different time frames, in which normally the client holds more responsibility towards later stages.

Review warranty policies
In total twelve different policies are reviewed for this research and these are described in appendix B. To give an overview of the findings and differences on these policies table 4 is created to be able to make a comparison between the different types of policy;

<table>
<thead>
<tr>
<th>Options:</th>
<th>Warranty dimensions</th>
<th>Renewing</th>
<th>Non-Renewing</th>
<th>Sort of warranty</th>
<th>Applicable to product category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warranty policies:</td>
<td>1D</td>
<td>2D</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Free Replacement Warranty (FRW)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2. Pro Rata Warranty (PRW)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3. Reliability Improvement Warranty</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>-</td>
</tr>
<tr>
<td>4. Rebate Warranty</td>
<td>X</td>
<td>o</td>
<td>-</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>5. Cost Sharing Warranty</td>
<td>-</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>6. Cost Limited Warranty</td>
<td>-</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Table 4: Overview of options for warranty policies

X = Confirmed in literature
o = Not appointed in literature but logical possible
- = Not referred to in literature

The given possibilities of warranty policies in table 4 providing an overview of the different warranty policies and the options to customize the warranty. The overlap of the warranty options on the proposed warranty policies is clear accept for the reliability improvement warranty. Reliability improvement warranty is a developed to improve a new introduced product over time so for that reason it is only applicable for extended warranty. In the first two policies are all options possible, this clarifies why these two are applied most common for base warranty on standard products.
4.1.4 Stakeholders

Role of warranty
Warranty is an integral part of most commercial transactions that involve product purchases. The buyer’s point of view of a warranty is different from that of the manufacturer. Individuals, cooperation, or governmental agencies represent the buyer and the manufacturer can be a distributor, retailer or a factory. Another group of stakeholders is the societ al group, they are represented by legislators, consumer affaire groups, the courts and public policy makers (Murthy & Blischke, 2006).

Buyer’s viewpoint
From the viewpoint of the buyer the main role of warranty is protection of the quality after the purchase transaction. If the product is properly used and it fails to perform, warranty provides a means to redress. Warranty assures the buyer that the product will be repaired or replaced on the account of the seller or at reduced costs. A second role of warranty is relation to the reliability of the product. Most buyers prefer a product with longer warranty period as a more liable product than one with a shorter warranty period (Blischke & Murthy, 1996).

Manufacturers viewpoint
One of the main roles or warranty from the viewpoint of the manufacture is also protection but in a different way than for the buyer. Warranty terms often specify the use and conditions of use for which the product is designed and if the product is misused, the coverage will be limited or expired. The manufacturer may be provided protection by specification of requirements for care and maintenance of the product. A second important purpose of warranty is marketing or promotional. This is related to the preference of the buyer who wants a product with longer warranty because it is more reliable; this is an effective advertising tool. In addition, warranty has become an instrument, similar to product performance and price, used in the competition with other manufacturers (Blischke & Murthy, 1996).

Societal viewpoint
Besides the direct stakeholders, the manufacturer and the buyer, the product is used in a bigger context. The rules and regulations of a country or countries apply on the products. Both the manufacturer and the buyer will have to face a broader set of rules of the society they act in. Murthy (2004) defines the stakeholders of the societal viewpoint as: legislators, consumer affair groups, the courts and public policy decision-makers. The rules and regulations formed in a society are there to protect the both the manufacturer and the buyer from engaging in unfair practices (Blischke & Murthy, 1996).

4.1.5 Process of warranty
The process of warranty is closely related to the product life cycle. In the following paragraph the product life cycle is used to explain the process of warranty.

Product Life Cycle
New (industrial) products or new type of (industrial) products are entering the market at an ever-increasing rate, mainly as replacement for existing products and also due to expanding of the businesses. Products can be approached from different viewpoints. Murthy and Blischke (2004) take the perspective of three different viewpoints namely the manufacturer, the production and the buyer or customer. The viewpoint of the manufacturer and production is taken as one viewpoint; the manufacturer (since this is the way it is structured for the case company, for this reason it is now chosen to simplify this viewpoint). The production is the third phase from the viewpoint of the manufacture and can be divided in four stages as shown in figure 10.
The product life cycle from the viewpoint of the manufacturer can be divided in the following five phases. The first two phases are also named the pre-launch stage and the last two the post-launch stage, naturally between these two stages is the launch stage.

- Phase 1 - Front-end: from the first idea to a go/no-go decision.
- Phase 2 - Design & Development: development of non-physical product solutions and construction of a prototype.
- Phase 3 - Production: coordination of materials, (production) processes, suppliers, etc.
- Phase 4 - Marketing: Distribution & promotion.
- Phase 5 - Post-sale servicing: all activities to ensure the satisfaction of the performance of the product over the lifetime. Spares, services, warranty, etc.

The lifecycle concept can be seen from two sides, the manufacturer and the buyer/customer. A relation between the manufacture and the buyer is a typical relation that is comparable with a seller and client relation and is applicable in all kinds of businesses.

From the buyers or customers’ point of view the product life cycle is the time from purchasing to discharging of the product. The phases are more consistent to the phases in the problem definition and are the following three phases:

- Phase 1; Acquisition
- Phase 2; Operations & maintenance
- Phase 3; Discard and replacement.

Both processes are different but they are dependent on each other; the manufacturer needs customers and in turn they need products from a manufacturer. The tension between these two stakeholders has everything to do with marketing and as already mentioned, warranty can be used as a way of marketing. A side note is that warranty has the most influence towards the end-user of the product, in the supply chain it will be less effective because of the business-to-business relationship (Murthy & Blischke, 2006).

**Link to case study**

It is important to link this literature research to the relevance of the case study later on. Therefore it is necessary to understand which part of the literature on the process of warranty must be further researched. For the case study company the product is already designed and developed. Therefore the post-launch stage is applicable to the case. The post-launch stage is divided in three phases as mentioned above. The industrial standard products are sold in a business-to-business market and therefore the marketing phase will be different from business-to-consumer markets. Marketing will only be done through exhibitions and external sales agents. The focus will be on the production and on the post-sale servicing phases to analyse the current situation. This analysis will be used to develop a new warranty service concept that can be eventually implemented in the pre-launch stage.
**Warranty as a strategic tool**
There can be several reasons to offer warranty. The reason is often connected to the strategy of the company in a broader context. A company can use warranty as strategy in two different ways: offensive and defensive.

Warranty as an **offensive** tool, the objective is:
- To offer better warranty terms (resulting in higher product quality)
- To gain a better position in the market (higher market share)

Warranty as a **defensive** tool, the objective is:
- To meet the competition, avoid losing sale;
- To correct misperception of the quality of the product by the customer;
- To limit liability.

When applying warranty as an offensive tool, free-replacement warranty (FRW) is a potentially suitable policy. While pro-rata warranty (PRW) can be used as a defensive way to offer warranty. A combination of FRW and PRW would be a reasonable compromise between these two.

It is important to realize that the potential risks between using warranty as an offensive or a defensive tool can vary hugely.

### 4.1.6 Warranty cost indicators
The dredging market for the case study deals with an already existing product based on an established design and production; the warranty costs in the post-launch phase are the most relevant. This paragraph will give a system approach to warranty cost analysis for the manufacturer of the products. When a product is sold with base warranty, the manufacturer will make an estimation of the costs dependent on several factors. These factors include: warranty terms, warranty duration, product reliability, etc.

It is important to take the commercial and the technical product design into account when estimating the warranty costs.

**System approach to warranty cost analysis**
In the book *Warranty Management and Product Manufacture*, written by Murthy and Blischke (2006), one of the main subjects is modelling the warranty costs. They developed two system characterizations for warranty cost analysis, one simplified system and another more detailed one.

The simplified system characterization for warranty costs is shown in figure 11.

![Figure 11: Simplified system characterization (Murthy & Blischke, 2006)](image-url)
The manufacturer produces and sells products to the consumer with a warranty policy. The product performance depends on the reliability and usage of the product, what involves the quality of the product from the manufacturer and usage from the consumer. If the product is not performing according to the agreed terms or non-conformity occurs, a warranty claim can be the result. The manufacturer has to service a claim, which results in warranty costs.

This system is considerably simplified which results in the following generalizations that need to be considered for this system approach:

- Consumers are represented as one, while there are many different consumers;
- All items are statistically similar;
- The performance is characterized in two states; working or failed;
- A failed item can be repaired or replaced;
- All submitted claims are valid (Murthy & Bliischke, 2006).

In figure 12 the detailed characterization of a warranty cost analysis from the perspective of the manufacturer is shown. The top boxes are equal to the last four phases of the product life cycle and are the major elements of manufacturing. The lower boxes are key element within each category, every element may involve one or more variables.

The number of claims per item during the warranty period is dependent of many variables, much more than in the simplified system. The elements that influence the number of claims in this model include; the product reliability, production quality, usage intensity, repair quality (in the case of repairable items) and the proportions of warranty claims that are valid and are executed. The prior mentioned variables influence all the warranty costs including the cost of servicing of each claim. The total warranty costs are also influenced by the sale rate to generate a total overview over the life cycle costs. All the elements are in the power of the manufacturer with an exception of the usage rate; the intensity of usage is in control by the consumer and this heavily influences the warranty costs as well.
The detail system characterization is an extension of the simplified characterization model and the details also limit the application of the model. The current system knowledge about the warranty in the dredging sector is limited, in combination with the intention to apply forward cooperation in the dredging sector is the simplified model the best option for now. In the future, when the development has progressed, the detailed model can become also an option.

### 4.1.7 Modelling product failures

The modelling of product failures can help to gain knowledge about the functioning of the product and therefore the warranty costs, as warranty claims are the result of system or component failures. Murthy (2004) describes alternate approaches to model product failure. A question that rises is which modelling approaches are there and how do they work? In the end of this paragraph different modelling approaches are elaborated. Modelling of failures is important to determine the potential product warranty costs. A failure occurs in an uncertain matter and is influenced by several usage factors:

- Usage mode (continuous or intermittent);
- Usage intensity (low, medium or high);
- Operating environment (normal or abnormal);
- Operator skills;

These factors are not in control of the manufacturer and have significant influence on the product behaviour and the warranty costs. When the warranty period is extended, the weight of these factors will grow. To offer extended warranty as a manufacturer of industrial product, it is important to find a solution to reduce the effect of these factors.

Dredging equipment is a standard industrial product, but also it is a complex repairable product that exists of many components and systems. Over the lifetime several failures are occurring, these failures can be influenced by repair and maintenance actions of the user.

By the modelling of failures several challenging issues will raise. Modelling can be done on different levels, at the system level or at component level or anywhere in between. The level is dependent on the available information and on the purpose of the model. Two examples; if the goal is to determine the amount and type of spare parts required, the modelling must be done at component level. On the other hand, if the goal is to determine the expected warranty costs, modelling on system level is sufficient enough.

### System approaches

The main system approaches can be split into two main categories, the white-box and the black-box approach. These two approaches are used to model a system or a component (box). The black box is referred to when the system or component characteristics are unknown. In this case the model is empirical or data driven. In other words: the input and the result of the (black) box are known, whereas the contents (system) are not.

On the other side of this system approach spectrum is the white-box approach. This can be seen as a glass box, where all the characteristics of the component or system are known. This white-box approach can be seen as the ideal situation to model a system.

In reality a system is most of the time not white or black, therefore the grey-box approach is a combination of the black and the white-box approaches. In this approach the gaps within a system or component are filled with further analysis or data (Murthy & Blischke, 2006).

- **Black-box approach**

A process or a system whose inputs and outputs (and the relationships between them) are known, but whose internal structure or working is:

- Not well (or at all) understood;
- Not necessary to be understood for the job or purpose.

The component or system is characterized in two states, working or failure.

**First Failure:** Modelling the time to first failure by using a continuous probability distribution or a hazard function. A hazard function is for many components a bathtub function, which is a characterization of the probability of failure over the age of a component. The mean time to failure (MTTF) is the average time to first failure.
Subsequent Failures: Subsequent failure is dependent on whether a component is repairable or not, if the component is non-repairable, the failure time is statistically similar to first failure. The time between subsequent failures of a repairable component is dependent on the type of repair.

Note: the repair or replacement time also need to be modelled, because this period is relatively small in relation to the life time the repair or replacement time can be seen as instantaneous (Khan & Khan, 2012; Murthy & Blischke, 2006).

- White-box approach
A process or a system whose internal structure or processing is known in addition to the knowledge about its inputs and outputs, and the relationship between them. Also called glass box.
There are different mechanisms of failure, two main groups dare over stress and wear failures.
Over-stress Failure: A component is subjected to stress over time, which affects and degrades the strength.
Wear-out Failure: Wear will increase the chance to failure of a component over time dependent on usage (Khan & Khan, 2012; Murthy & Blischke, 2006).

- Grey-box approach
The grey-box approach uses the knowledge about partially internal structures or systems, which includes access to the documentation and functional specifications. Also called semi-transparent approach (Khan & Khan, 2012; Murthy & Blischke, 2006).

Component and system failures
Linkage between component failure and system failure:
- Forward approach (bottom-up): from part level to system level. Start with a failure at part level and workout the consequences at system level or performances. Method: Failure mode and effects analysis (FMEA)
- Backwards approach (top-down): from system level to part level. Start at system level and proceed to part level to make the linkage of system performance to part level. Method: Fault tree analysis (FTA)

- Failure mode and effects analysis (FMEA)
Decomposing a system in terms of system, sub-system, assemblies, till part level. Used to identify the failure modes and causes including the effect of the failure. (Murthy & Blischke, 2006)

- Fault tree analysis (FTA)
A logic diagram that displays the relation between a potential event affecting the system performance and the reasons or causes for the event is a FTA. The reason or cause can be failure, environmental conditions, human errors and other factors.
A fault tree illustrates the state of the system (top event) in terms of the states (working/failed) of the system’s components (basic events). The connections are done using logical gates, where the output from a gate is determined by the inputs to it (Murthy & Blischke, 2006).

With the current knowledge about the product properties of dredging equipment from the viewpoint of the supplier, the black box approach is the most suitable method for modelling product failures. When relating this to the system related failures, the backwards approach (FTA) is the best option to determine the component & system failures. When more knowledge on the product properties is available it will eventually be possible to able apply a white box approach and to implement a failure mode and effect analysis.
4.1.8 Concluding: relevant learning’s from literature on warranty for case study

Regarding the right description of warranty the definition by Murthy & Blischke (2006) is used. Important elements of this definition are that warranty is mostly a ‘contractual agreement’ that specifies ‘product performance, buyer responsibilities and what the warrantor will do if an item purchased fails to meet the stated performance’.

The concept and understanding of warranty has changed significantly over time. Concluding on three theories of warranty over time, it is known that warranty became an important indicator to secure the quality of a product, and the offering of warranty allows a manufacturer to differentiate from its competitors using it as a tool to increase competitive advantage. The positive effect of warranty on the product quality is part of the manufacturing strategy, while the effect on the competitive advantage is part of the marketing strategy. Therefore the strategic warranty management takes into account the warranty related decision problems on both the operational and commercial strategy levels. For the case study it is important to notice that warranty does not only affect technical or operational strategies but commercial strategy as well.

The different types of warranty can be distinguished on the dimension of warranty (one- or two-dimensional), the sort of warranty (base or extended) and whether the contract is renewing or not. In total twelve different policies were discussed and compared in this chapter, of which it cannot yet be determined which one might be appropriate for the case study.

The process of warranty is closely related to the product life cycle in which the pre- and post-launch stages are distinguished for the manufacturers’ perspective on the process. At first instance this research focuses on the post-launch stage for the analysis since this is applicable to the case study. Only then these insights will be translated to the pre-launch stage for the case study to be able to eventually implement a new service concept. Within all these stages warranty can be used both as an offensive as well as a defensive tool, for each of these scenarios the potential risks can vary hugely.

The financial aspects were also explored and two different system characterizations developed by Murthy & Blischke (2006) to model warranty costs were compared; a simplified model and a more detailed model. In the simplified model the product performance is influenced by the product reliability and the product usage. Combined with the warranty policy these three main elements (directly or indirectly) determine the warranty costs. Most elements are in control of the manufacturer with an exception of the product usage; the intensity of usage is in control by the consumer and this heavily influences the warranty costs as well.

Finally the modeling of product failures is discussed, this modeling can be done both on the system- and on the component level. This research focuses on the system approach since the goal is to determine the expected warranty costs.
4.2 Forward cooperation

The problem definition concluded that there is need for a method or agreement to fulfil forward vertical cooperation by offering professional services to the client. Auguste, Harmon and Pandit (2006) analysed the strategy of product companies in relation to offering services. They conclude that the aim of a product company offering a service is merely to support and to strengthen the product. The production of dredging equipment is a business that typically relies on the economies of skill because of the required specific knowledge and experience for the design and building phases. Often the dredging equipment suppliers offer several supporting services for their capital goods. There are many other ways to improve the relationship with the client and to support the product (forward cooperation). Options like integrated contracts, Service Level Agreements, Extended warranty and Maintenance service contracts. This sub-chapter will elaborate on these different options and will conclude with the best option to achieve forward integration.

4.2.1 Integrated contracts

Which method or agreement to fulfil forward vertical cooperation is suitable still has to be explored. By gaining knowledge from the civil engineering perspective, different contracts will show that cooperation could be achieved (forward) between the client and the supplier. Integrated contracts in the civil engineering sector have grown over time into a large variety of different contract forms. Public private partnerships (PPP) and especially Design, Build & Maintain (DBM) contracts are commonly used for civil engineering projects and are recently used in the Netherlands too, compared to for example the United Kingdom where they have used these forms of contracts for a longer period of time already. To provide an insight in the different contracts used in the civil engineering a list and explanation is made in this subparagraph. When making a comparison to the civil engineering sector it is good to emphasize that public organizations are often involved as important stakeholders in civil engineering projects while this may not have to be so for the maritime industry. To give an overview figure 13 shows which phases of the project lifecycle are covered by these contracts. Followed by a description of all different contract possibilities.

Figure 13: contract overview (Rijkswaterstaat, 2013)
Traditional or RAW contract
These are traditional contracts that were standardly used for civil engineering projects in the Netherlands. The client is responsible for all phases up until the building phase. For the purpose of the building phase standard contract forms are used in which the material, method and quantity are all precisely described.

Design & Construct (D&C)
In case of a Design & Construct contract the contractor is responsible for the general design, detailed design and preparation for execution of the project and for the construction of the project. It is important for the success of the project that the client defines clearly the project constraints in the form of a set of requirements. During the realization the client will only supervise the project.

Turn Key
The Turn key-organization is responsible for the total design and construction of the project. The client will only be responsible for the initiative and sometimes for a feasibility study. The client takes over the responsibility during the commissioning to ‘turn the key’. A turnkey contract is closely related to performance contracts.

Design Build & Maintain (DBM)
A Design, Build & Maintain contract is a D&C contract linked to the maintenance for a period of n-years. The contractor is also responsible for the maintenance that is required during the exploitation of the project. In a DBM contract the contractor is challenged to design and construct for maintenance. The operation costs are an important factor during the tender phase.

Design Build Maintain & Finance (DBMF)
This contract is an extension on a DBM contract including the financial aspects of the project. The contractor is now also responsible for the funding of the project; most of the times a financial partner is then involved in the joint venture. The finance method can be distinguished in pre-financing, post-financing or finance by property developments (Rijkswaterstaat, 2013).

Public Private Partnerships
A Public Private Partnership (PPP) is a partnership involving a public-organization and a private-company that jointly create a project based on a clear division of risks and tasks. The aim of the partnership is to create an overall better result; higher quality for the same or a lower total price. Since recently the public organizations are more oriented on closing a contract with private companies on the longer term, therefore the market for public private partnerships is growing (PPS-Netwerk, 2015). The public organizations provide private companies the chance to reduce project costs while at the same time guarantee quality (Rijkswaterstaat, 2013).

In his book about the principles of Public Private Partnerships Yescombe (2011) described the following key characteristics for this contract form:

- A long-term contract between a public-organization and private-organization;
- For the design, build, financing and operation of public infrastructure by private-companies;
- With payments during the time of the PPP contract to the private-company for the use of the facility, made either by the public-organization or by the general users of the facility;
- With the facility remaining in the public-organization ownership, or reverting to the public-organization at the end of the PPP contract (Yescombe, 2011, p. 3).

The difference between the approach from Rijkswaterstaat and Yescombe is the perception of duration of the contract. A PPP contract can be applied for only the design and building phase or also for the maintenance and operation phase of the project. This depends on the purpose of the project. The long-term contracts will give an extra advantage to the private-companies because it will generate a constant workload and income over a longer period (Rijkswaterstaat, 2013; Yescombe, 2011).

With this knowledge of contract forms used in the civil engineering sector, the DBM contract is the most suitable option for forward cooperation in the dredging industry. Currently the dredging industry uses contract forms similar to the Design & Construct contract forms in the civil engineering industry. The most natural extension from the Design & Construct contract form is to the DBM contract form, as can be concluded from figure 12 where the covered phases of the project lifecycle are shown.
A contract similar to the PPP contract, where the highest aim is to build a partnership to share the risks, is yet a step too far for this industry. However the general trend for the future will be that the parties will cooperate more - in the dredging industry as well - during the lifecycle of the equipment. On the long term the other contract forms that cover extended phases of the lifecycle might also be interesting for the dredging equipment sector, however implementing this on the short term is not viable for this industry yet. It is necessary for the suppliers in the dredging sector to get familiar with those contract forms that cover more phases of the lifecycle before reaching for the ultimate coverage of all lifecycles. By gaining experience in these intermediary contract forms the chance of success will be enhanced.

4.2.2 Service Level Agreement
The findings of out of the problem analysis conclude that there is a need for a method or agreement to fulfil forward vertical cooperation by offering professional services to the client. There are many strategies to offer professional services, service plans, service level agreements, service contracts, etc. A Service Level Agreement (SLA) is a type of service contract with broad application and used to be regularly applied and found in the IT-sector. Nowadays SLAs are applied in many other sectors including: healthcare, facility management & the security sector and are the properties adopted for diverse applications.

A service level agreement basically is an agreement between two or more parties in the ratio of the supplier and client of a product or service. In the agreement is described what the rights and obligations of both the supplier and the client with respect to the agreed quality (service level) of the services or product to be delivered (CLARKSON) (Maas & Pleunis, 2006). The legal binding can be a formal or an informal contract, however intern contracts are mainly informal.

The SLA can be agreed on different levels, because this research is about the niche market in combination with the aim for professional services, the SLA will become a customer-based SLA. A customer-based SLA is an agreement with a specific customer group, covering the service they require (Ahmad, Ahmad, Saqib, & Khattak, 2012). Initially the important intentions of a service level agreement are to:

- Identify and define the customer’s needs;
- Provide a framework for understanding;
- Simplify complex issues;
- Reduce areas of conflict;
- Encourage dialog in the case of disputes;
- Eliminate unrealistic expectations (SLA-Zone, 2007).

Service Level Agreements are often based on measurable service performances or key performance indicators that correspond to the service level objectives. Metrics are commonly agreed between the supplier and client on parameters like; Time Service Factor (TSF), Turn-Around Time (TAT), Uptime, Mean Time To Repair (MTTR) or Mean Time Between Failures (MTBF).

In fact, when approaching the situation from the point of view of the client, a service contract is a method of outsourcing responsibilities to the supplier. The transfer of responsibilities is a consideration made according to the finances, risks and available experienced staff. Outsourcing services is most efficient when the supplier is better in handling the service activities than the owner. This is closely related to risk management, without going into detail, the most efficient way of managing risks is when a risk activity is managed by the party who is able to control the activity. Of course the outsourcing of services is closely related to the financial considerations (Hillson & Simon, 2007).

4.2.3 Extended warranty
Extended warranty is also commonly described as a service or maintenance agreement. From consumers’ perspective extended warranty is often considered as the prolongation of warranty after the base warranty on new items expires.

Extended warranty
Extended warranty and maintenance service contracts are similar in many aspects but there are also differences. A proper understanding of base warranty is required to understand the extended warranty
concepts. Base warranty is an integral part of the sale of a product and the customer has no understanding of the warranty costs because it is included in the sales price. The terms of base warranty for standard products are formulated by the manufacturer. In case of complex or custom-built products the terms are jointly decided. The manufacturer and customer can include reliability performance in the warranty policy. This requires the manufacturer to ensure meeting the reliability performance targets, this is referring to Reliability Improvement Warranty policies. The purpose of Reliability Improvement Warranty is to agree on terms that will motivate the manufacturer to continue to improve the reliability after the product is delivered. Originally, only the manufacturer offered Extended Warranty. Currently, Extended warranty is mainly offered by other service providers (such as retailers, insurance companies and other parties) rather than by the manufacturer only (Murthy & Jack, 2014).

**Base warranty as basis for extended warranty**
The literature related to base warranty is very extensive, mainly because base warranty is applied for a long time and for many products. Blischke and Murthy (1996) distinguished four topics of base warranty that are important for the context of extended warranty:

1. Warranty cost analysis;
2. Warranty and marketing;
3. Warranty management;
4. Warranty logistics.

These four topics are already briefly discussed in the first part of this chapter.

**Key elements of Extended Warranty**
Murthy and Jack (2014) have listed the key elements of extended warranty. The elements are listed below and some or all elements are important for extended warranty.

1. **Extended warranty provider**
The extended warranty can be provided by the original manufacturer but also by a retailer or a third party such as insurance providers or credit card companies.

2. **Purchase date and duration**
The customer is often obligated to purchase the extended warranty at the moment of purchasing the product. It can also be that the customer has the possibility to purchase the extended warranty at any time until the end of the base warranty. The duration of extended warranty can be limited either only by the time (one-dimensional) or limited by both time and usage (two-dimensional).

3. **Terms**
The terms define what the extended warranty covers in relation to labour (full, partly or not covered) and material (components or parts covered). With full coverage of labour and materials the customer is in advance ensured of the costs during the time of extended warranty. In all other combinations the costs are depended on the terms agreed upon by the stakeholders.

4. **Exclusions and limits**
Exclusions and limits related to the claims during the extended warranty period can be made on different items. Murthy and Jack (2014) give the following exclusions and limits:
   - Transport or freight costs excluded and paid by the customer;
   - Parts of the product not covered;
   - Limits are placed on the total number of claims;
   - Cost limits—limit on each claim, limit on total claims.

5. **Price**
The price is an important element of the extended warranty. The purchase price of the extended warranty can be one fixed price or divided in options and packages, often the price is expressed in a percentage of the product price.

6. **Special requirements**
The manufacturer can state special requirements to the customer related to regulated maintenance actions. For example; a specific, authorised dealer needs to carry out the repairs of the product in order for the customer to maintain the rights to make a claim. In this way the manufacturer can keep control over those involved in different phases of the product life cycle, making sure the product quality is safeguarded even during repairs.

Extended warranty policies
Regarding the existing policies for extended warranty on products in general many variations are possible on the policy itself. For this research several policies are researched in more detail to explore which one is most suitable for the dredging equipment sector. The analysis of these policies can be found in appendix B. Which policy, or combination of different policies, is most appropriate still has to be decided, this will be done when the different findings are combined during the case study.

4.2.4 Maintenance service contracts
A Maintenance Service Contract (MSC) is a legal document (or contract) that is binding on two parties (the service provider and the customer) and can be divided in three issues namely; technical, economic and other issues (Murthy & Jack, 2014).

Technical issues
There is a growing trend towards functional specification of contract conditions. In these contracts the output level for the products is specified. The service provider has the freedom to decide what kind of maintenance is required and when to execute the maintenance work. These contracts also need to describe the restrictions to the usage intention, operational conditions and other issues influenced by the customer (user).

Economic issues
A maintenance service contract is most efficient over a longer period and therefore they comprise long-term contracts. A critical decision point for this contract form is the payment structure, some examples of structures are; fixed or firm price, variable prices, price ceiling incentive. Other cost plus examples are; cost plus incentive fee, cost plus award fee, cost plus fixed fee and cost plus margin. All the different payment structures represent a different level of (financial) risk sharing between the customer and the service provider.

Other issues
Other issues are all issues that need to be described to make the expectations clear to both parties. When the contract is written properly and the customer analyzes all relevant data properly, the long-term costs and risk will escalate. Other issues can be for example requirements on contract duration, moral hazard, and dispute resolution.

Maintenance activities
Maintenance of a product can be linked to three different activities as indicated in figure 14.
During each phase the following questions regarding maintenance need to be answered:

1. Work planning (D-1): What needs to be maintained?
2. Work scheduling (D-2): When should the maintenance be executed?
3. Work execution (D-3): How should the maintenance be organized?

Relating the different maintenance activities and the two parties (customer and service provider) three different scenarios for maintenance responsibility can be created.
Scenario 1 is the minimalist approach of outsourcing, the service provider provides only the resources. In Scenario 2 the customer only decides what has to be done, when and how is for the responsibility of the service provider. In Scenario 3 the service provider makes all the decisions, he is then responsible for the total maintenance.
Scenarios | Decisions | Service provider
---|---|---
Scenario 1 | D-1, D-2 | D-3
Scenario 2 | D-1 | D-2, D-3
Scenario 3 | - | D-1, D-2, D-3

Table 5: Maintenance scenarios (Murthy & Jack, 2014)

**Contract perspectives**
By having two parties (the customer and the service provider) and three possible dominance levels (equal, leader or follower) three basic scenarios are created in table 6.

<table>
<thead>
<tr>
<th>Customer</th>
<th>Service provider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>Leader</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>Follower</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>Equal; neither leader or follower</td>
</tr>
</tbody>
</table>

Table 6: Three scenarios

The scenarios are going hand in hand with the responsibility for the materials, parts and labor required to execute the maintenance works. Combining scenario 2 and the full responsibility for all materials, parts and labor is related to **functional guarantee contracts** (Murthy & Jack, 2014).

### 4.2.5 Conclusion
Since the dredging industry is not yet familiar with the method of forward cooperation, this chapter 4.2 has explored different concepts of forward cooperation in other industries. The term 'integrated contract' stems from the civil engineering industry and is a collective noun for different contracts covering different phases of the product lifecycle. For this research a comparison with the civil engineering sector is made to explore what analogies can be made for the maritime industry. Since integration across different phases of the life cycle is relatively new to the maritime industry it is not preferable to copy the concept of integrated contracts. Some interesting lessons learned in the civil engineering industry are explored to transfer these to forward cooperation in the maritime industry.

The concept of extended warranty is more generally known for (consumer) products since it builds further upon the notion of base warranty. Other concepts such as maintenance service contracts and service level agreements are not yet used in the maritime industry but they are certainly familiar to the manufacturers within this industry since they recognize the opportunities of these contracts. To give an overview of the properties of different contracts or agreements explored in this chapter 4.2 table 7 is created to summarize the main findings.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Service Level Agreements (SLA)</th>
<th>Maintenance Service Contracts (MSC)</th>
<th>Extended warranty (EW)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product type</strong></td>
<td>Custom built, Product group</td>
<td>Custom built, Product group, Standard products</td>
<td>Standard products (consumer, commercial &amp; industrial)</td>
</tr>
<tr>
<td><strong>Contract formulation</strong></td>
<td>Service provider &amp; customer</td>
<td>Service provider &amp; customer</td>
<td>(Original Equipment) Manufacturer</td>
</tr>
<tr>
<td><strong>Relationship to base warranty</strong></td>
<td>Different</td>
<td>Different</td>
<td>Similar</td>
</tr>
<tr>
<td><strong>Time to purchase</strong></td>
<td>Any time</td>
<td>Any time</td>
<td>At product sale</td>
</tr>
<tr>
<td><strong>Customisation to meet customers needs</strong></td>
<td>Service level can be adjust to customer</td>
<td>Level of customisation can vary to meet the customers needs</td>
<td>Choosing between few options, limited customisation</td>
</tr>
<tr>
<td><strong>Complexity of contract</strong></td>
<td>Medium-High</td>
<td>Medium-High</td>
<td>Low-Medium</td>
</tr>
<tr>
<td><strong>Initiator</strong></td>
<td>Customer</td>
<td>Customer</td>
<td>Extended warranty provider</td>
</tr>
<tr>
<td><strong>Process of selection</strong></td>
<td>Complex</td>
<td>Complex; involving auctions, tendering, etc.</td>
<td>Simple</td>
</tr>
</tbody>
</table>

Table 7: Comparison of SLA, EW & MSC
Dredging suppliers produce approximately 20 dredgers every year. The dredgers vary only little from each other and can be seen as a standard product. A Service Level Agreement (SLA) is complex and mostly applied for custom-made products and the agreements are therefore also custom made per product or service. A Maintenance Service Contract is also a complex contract form and the application can vary to all types of products. A custom-made product asks for a custom-made agreement and a standard product can be strengthened with a standard agreement. Since the dredging equipment can be seen as a standard product with intention of the manufacturer for forward cooperation the application of SLA and MSC will be less appropriate.

The supplier of dredging equipment offers one-year warranty to their clients at the product sale. The obvious step to achieve forward cooperation from that point is to extend the current warranty. The next step could be to offer a MSC or a SLA to clients at any time of the usage period.

With the properties of the dredging market and the intention to achieve forward cooperation in the product life cycle of a standard industrial product, extended warranty has the best characteristics.

4.2.6 Reflection on D.N.P. Murthy & W.R. Blischke

The book which is mainly used for the literature within the literature study is the last part in a trilogy of books about warranty management. As is described in the introduction of the book ‘Warranty Management and Product Manufacturer’ the book focuses on the linkage of warranty and the product life cycle. This is in line with subject of this research and explains the connection.

Business to client

The books written by D.N.P. Murthy & W.R. Blischke mainly focus on the involvement of product warranty and the relation between the manufacturer and the user of the product (business to client). The described warranty relation is for products that are commonly produced in large numbers. Most of the mentioned cases are based on products produced in large numbers.

This has to be taken in account when performing/applying the literature on a business to business market; certain scale advantages may not apply so that the distribution of income, risks and costs can be reduced.

The models described are developed for a business to consumer market and these large quantities of warranty claims are all treated in the same way and by the same restrictions. The case study used in this research is conducted in a niche market where a close/tight relation with the client is developed during the first year of warranty. All delivered products have their personal contact for warranty related issues. This influences the treatment of the warranty claims as well. The assessment of a claim in this niche market cannot be treated ‘black and white’. Moreover the claim assessment is influenced by potential sale leads and claims can be approved easier when the same client has the intention to place an order. These different methods of approaching the evaluation of warranty claims have their effect on the gained results as well.

Evaluation of the warranty in the post-launch phase

The models described by D.N.P. Murthy & W.R. Blischke are made to analyse warranty costs in the post-launch phase but not to develop warranty. In this research is focused on developing a model to provide extended warranty in the pre-launch phase. The theory of D.N.P. Murthy & W.R. Blischke provide a good insight in the characteristics of warranty and is used to analyse the current situation. Furthermore, it is used as foundation to develop a new framework for extended warranty.

Marketing of warranty

The described models have been developed from the perspective of a manufacturer to determine the warranty costs. Ultimately, it is important to know what the warranty costs are. Above all extended warranty is not mandatory and because of this the marketing of the extended warranty is important.

From a technical product point of view, the methods described in this book are designed to determine the warranty costs. The book mentions that extended warranty could be a marketing strategy however this book considers a technical point of view and not a commercial point of view. From a commercial point of view, the marketing of warranty is yet little described.
5. IST situation

This is the first chapter which deals with the single case study at Royal IHC. First, the general approach for the analysis of the IST situation, SOLL situation and the GAB will be discussed, in order continue with the analysis of the IST situation.

5.1 Research method for the case study

In order to distinguish the current and the proposed situations the variables of the simplified model of Murthy (2006) are used in an assessment table. These variables are listed in the rows of the table and assessed on three points. To clarify the variables and assessment points they are explained below.

<table>
<thead>
<tr>
<th>Assessment points:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who’s in control?</td>
</tr>
<tr>
<td>Fixed / variable</td>
</tr>
<tr>
<td>Known / Unknown</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variables:</th>
</tr>
</thead>
<tbody>
<tr>
<td>A – Warranty policy</td>
</tr>
<tr>
<td>B – Product Reliability</td>
</tr>
<tr>
<td>C – Product Usage</td>
</tr>
<tr>
<td>D – Warranty Costs</td>
</tr>
</tbody>
</table>

Table 8: Assessment Table

Variables on the vertical axis

A. Warranty policies

The warranty policies are integrated in the sale conditions. The warranty terms are dependent on the selected terms & conditions and warranty period. In the terms & conditions detailed information can be found about: (i) distribution of costs, (ii) dimensions of the warranty (restricted by time and/or usage), (iii) distribution of responsibilities and (iv) design specifications.

B. Product reliability

The product reliability is determined by the manufacturer and is affected by; (i) the design, (ii) the used materials & products and (iii) the quality of the production. The product performance however is not determined by the product reliability on its own but is determined in combination with the product usage.

C. Product usage

The usage of the product is determined by user of the product and is influenced by the following factors; (i) usage mode, (ii) usage intensity, (iii) operating environment, (iv) operator skills & (v) maintenance. The product usage and the product reliability determine the product performance, which influences the warranty costs.

D. Warranty costs

The warranty costs are dependent on the product performance (product reliability & usage) and the warranty policies. The warranty costs are a direct result from the choices that are made for the design and the choices of the customer. In the IST situation the warranty costs for one year are known and can be used as a derivative to check the SOLL warranty costs.

Variables on the horizontal axis

The variables on the horizontal axis are used to assess the above influencers and are therefore named the assessment points.
Who’s in control?
In the first column the stakeholder that has the most influence on the vertical axis variable is defined. This can be the supplier or the client, or both. Thereby the question asked is: does the supplier control the variable or does the user control the variable?

Fixed/variable
In the middle column the variables of the vertical axis are assessed based on whether the situation is fixed, variable or controlled. The variables are assessed from the viewpoint of the supplier, in the case study Royal IHC. A vertical variable can be fixed by the supplier (meaning the outcome is known in advance) or influenced by the usage of the client and therefore variable. The variable is controlled when the outcome is within acceptable boundaries.

Known or unknown
In last column the vertical variables are assessed on the information that is available for the suppliers to assess the variable. When the variable is known it is clear that the behaviour of the variable is set. When the variable in unknown there are still some variation of knowledge possible. To make a distinguishing in there are three possibilities for the unknown shown in table 9. Relating this to the potential risk, the risk will increase when the variable becomes more unknown.

<table>
<thead>
<tr>
<th>Known or unknown</th>
<th>Visualization</th>
</tr>
</thead>
<tbody>
<tr>
<td>◆ Known</td>
<td><img src="image" alt="Known" /></td>
</tr>
<tr>
<td>◆ Unknown, known based on correlation of data</td>
<td><img src="image" alt="Unknown, known based on correlation of data" /></td>
</tr>
<tr>
<td>◆ Unknown, known based on experience</td>
<td><img src="image" alt="Unknown, known based on experience" /></td>
</tr>
<tr>
<td>◆ Unknown</td>
<td><img src="image" alt="Unknown" /></td>
</tr>
</tbody>
</table>

Table 9: Known/unknown distinguishing
Warranty policy

This paragraph will elaborate the first variable of the simplified characterization; the warranty policy. The analysis of the warranty policy is based on the IHC Beaver 50. Before going into the context of the terms and conditions of the IHC Beaver dredger, there is an explanation on why IHC is currently giving warranty in relation to the Dutch law.

5.2 Legislation of Warranty within the Netherlands

Business to Consumer (B2C) context
When referred to the term ‘warranty’ people generally think of the concept of warranty related to consumer products; in the context of the so called ‘Business to Consumer’ (B2C) relationship. The legal warranty for consumers is laid down in the Civil Code of the Netherlands (Article 17, clause 2 BW7) and is called the conformity principle. This principle states, “a product should meet the requirements that a consumer can reasonably expect” (translated from Dutch). In the law the right of the customer is described and it is stated that the seller should not limit this right. Besides the legal warranty various forms of additional warranty are possible such as; seller warranty, manufacturer warranty and importer warranty (Ondernemersplein, 2014).

Legally there is no term for the duration of the warranty, however “the consumer has the right on a ‘solid’ or ‘sound’ product” (Article 17, clause 2 BW7) (translated from Dutch). Many consumers but also firms suggest that they have a minimal right to warranty period of two years. Indeed, the European Guidelines of Warranty [Europese Richtlijnen Koop & Garantie] set out a legal minimal period of two years for warranty on consumer products. However each Member State of the European Union is allowed to make adjustments to this rule as long as the outcome is in favour of the consumer. The Netherlands has chosen not to adopt this guideline and applies the description that the product needs to be ‘solid’ or ‘sound’. This implies that the consumer must be able to use the product for a certain amount of time. The product is not ‘solid’ when it does not meet the requirements reasonably acceptable when the product is used in normal conditions (Ondernemersplein, 2014).

How a consumer sets an expectation of the product depends on (several of) the following aspects:
- The sort of product;
- The sales price;
- The expected lifespan;
- The supplier or channel of sales;
- The information provided by the sales person;
- Other information from the brochure, internet etc. (RVO, 2014).

Business to Business (B2B) context
When a firm supplies a product to another firm this is called ‘Business to Business’ (B2B). The warranty for a product supplied via B2B does not hold a legal warranty. Unlike the warranty for B2C products, where the law protects the consumer, for B2B products this is far less defined. Clients in the B2B context are expected to have knowledge about the product that the buyer intends to purchase for business purpose. The business client is supposed to be able to use the product normally for a certain amount of time. The supplier needs to inform the client about the characteristics of the product. In a business agreement (B2B) it is possible to negotiate about individual clauses. The final agreement must meet the requirements of ‘reasonableness & fairness’ (redelijkheid & billijkheid) (RVO, 2014).

General conditions
In the general conditions of a business agreement (B2B) a clause can be incorporated related to the warranty, for example when the purchaser renounces the right to non-conformity. The general conditions need to be handed over to the buyer before the contract is signed. The clause in the general conditions must meet the requirements of ‘reasonableness & fairness’ (redelijkheid & billijkheid). A clause in the general conditions is defeasible if unreasonably onerous. The buyer himself will have to appeal to the seller in the courts. Companies can negotiate a business deal on a particular term. An example can be an agreement where the seller in exchange for price reduction renounces his right to non-conformities (RVO, 2014).

Concluding, in the supply of products to businesses, different laws and regulations are valid as opposed to consumer products. The consumer is protected by the law and cannot be limited by the seller; a consumer has the right on a ‘solid’ or ‘sound’ product. Companies can negotiate about individual clauses in the general conditions as long as it meets the requirements of ‘reasonableness & fairness’ (redelijkheid & billijkheid).
Legislation related to the IHC case
When applying this knowledge to the situation at IHC and combine it with results of the interviews - knowing that IHC operates in the ‘business to business’ context - it means that IHC is not obligated to provide warranty as long as the product (dredgers) meets the requirements of ‘reasonableness & fairness’. The warranty of at least six months is incorporated in the general terms and conditions to clarify to the customer what the content of warranty is. If the client requests for 12 months of warranty it will be incorporated in the contract for the same price. Thereby the difference between the warranty period of six and twelve months for the Beaver dredgers is mainly a marketing aspect in forms of negotiation space for the seller. Most Beaver dredgers (75%) are sold with a warranty period of twelve months.

5.2.2 IHC Terms and conditions
When talking about the warranty for a product like a Beaver dredger, the basic terms and conditions are established in two phases (i) the procurement phase and (ii) the sale phase. From the viewpoint of a supplier of dredging equipment like IHC, there are two important groups of stakeholders; the clients and the sub-suppliers with IHC in between. For both stakeholder groups terms and conditions are drafted with the purpose of procurement of parts (from IHC to the sub-suppliers) and sale of products (from IHC to the client).

The general terms and conditions are state rules that apply to the seller and the buyer of the product or services. The terms and conditions will provide guidelines in payments, delivery times, warranties and disputes. In the Netherlands several sector organizations, suppliers and clients, have mutually drawn up their standard terms and conditions (KvK, 2015). Even than a disagreement on the terms and conditions is not an exception, also known as the ‘battle of forms’. The issue of ‘the battle of forms’ often arises when both parties attempt to impose their respective standard terms and conditions. The result is often that neither of the parties is sure which terms and conditions prevail. Usually strict rules of offer and acceptance apply. An example; “when a supplier offers to a contract on its own terms and conditions, and the client accepts but replies with its own terms and conditions in the attachment. If the supplier continues to provide the goods or services without expressly addressing the issue, it is considered that the supplier has accepted the counter offer including the terms and conditions. Therefore the terms and conditions of the client apply on the contract, because the client ‘fired the last shot’ and won the so called ‘battle of forms’” (Baird & Weisberg, 1982).

IHC is the designer and builder of the Beaver dredgers, most of all the large steel parts (like the hull and the dredging installation) are built at one of the IHC premises. But many other important parts and systems are delivered by other companies (sub-suppliers) to IHC. So, in the position of IHC terms and conditions for procurement are required, as well terms and conditions for sale. The relation to different stakeholder groups is visualized in figure 18. The figure shows that IHC has three roles, one of a client from the sub-supplier, one as the builder and the last one as a supplier towards the client. Notable is that there are several terms and conditions applicable at the ‘sale’ side and only one at the ‘procurement’ side, this will be further elaborated in this paragraph.
The terms and conditions from IHC to the client or customer, the ‘sale’ side, are divided into two parts. The first part exists of the ‘IHC General Conditions’ and the ‘VNSI General Yard Conditions’, these two conditions are always used in combination and are standard to all tenders and offers towards the client. The second part is the ‘contract for the construction and supply of dredging equipment’ and is only applied in case of an agreement for the construction and supply of equipment. The latter document is more extensive than the general terms and conditions.

The ‘procurement’ side is intended for the delivery of services and goods towards IHC, here is where the battle of forms can appear.

The purpose of elaborating the general condition of IHC is to determine the basic condition of the IST situation. The terms and conditions are important for the coverage of the warranty risks and will become more important when the warranty will be extended.

As described, there are two sections:

- The sale conditions are submitting the agreement with the clients. If the client buys an IHC product with a warranty period, IHC is ultimately responsible.
- Within the procurement condition IHC is willing to move some warranty responsibilities to their sub-suppliers for the supply of their components. This is specified in the procurement conditions and is important to reduce the risk of IHC.

This paragraph discusses the sales and procurement conditions for the IST situation and goes into more detail on the main topics. For later research it will be interesting to investigate how the warranty is performed in reality compared to the terms and conditions.

5.2.3 Terms & conditions sales at IHC

IHC General Terms

‘The general conditions apply to the supply of goods by IHC to a client or customer and if other general conditions from the client or customer are not applicable’ (IHC, 2005). This is a quotation from the first chapter of the IHC General Terms document. The general terms are added to all official offers & tenders IHC signs up to. The focus will be on the terms related to the warranty issues and in between IHC and the client or customer. Additional to the IHC General Terms are the VNSI General Yard Conditions these conditions are also part of this paragraph.

Findings IHC General Terms

The IHC General Terms be found in appendix C1. Only article 6.1 is related to the warranty of the dredging equipment, the other articles in this clause are related to the liability between IHC and the customer. The last clause in the IHC General Terms, clause 9 is referring to VNSI General Yard Conditions as an addition to the IHC General Terms.
Summarized the IHC General Terms in relation to warranty give the following information:

- Warranty period: standard six months, often extended to twelve months;
- Starting at: the date upon which the good is ready for delivery;
- Rectifications of the faults in construction and/or replace fault components at IHC premises;
- Or repair and/or replacement can be done elsewhere in consultation with IHC for the same price of recovery by IHC;
- The liability for the dredging equipment is upon the date that the good is ready for delivery for the customer.

VNSI General Yard conditions
The Dutch Shipbuilding Industry Association (VNSI) represents the interest of the Dutch shipbuilding and ship repair industry. The VNSI supports and provides the sector in education, environmental issues, regulations, and all other multi sectorial interests.

Findings VNSI General Yard conditions
Out of the VNSI General Yard Conditions only chapter 12 is related to warranty and can be found in appendix C1. The VNSI General Yard Conditions are an addition to the IHC General Terms and only applicable in this combination. Article 12 is totally devoted to guarantee related issues. The following bullets will give a summary of the most important issues:

- Warranty period: standard 3 months;
- At delivery: the liability will shift from IHC to the customer, and the guaranty period starts;
- Defects will be repaired or replaced at IHC premises;
- IHC is only responsible for the defect itself and not for consequential losses;
- Repair at third parties is possible, in collaboration with IHC and for the same price as IHC was able to repair;
- If the customer fails in the performance of any obligations related to this agreement, the guaranty obligation will expires;
- Externally delivered parts will only have the warranty related to the terms of the supplier;
- In case of an unjustified claim all costs are for the account of the customer.

IHC contract for the construction and supply of dredging equipment
The word 'contract' already points out that this document is the most extensive of the sale terms & conditions for both parties. Within IHC a contract is prepared for the sale of a dredger. The client is at that point already familiar with the IHC General Terms from the proposal phase. A contract also offers more options to adjust the terms & conditions together with the client. The results below are only focused on the guarantee & liability of a random selected contract; afterwards a short summary is made of the most important terms.

Findings IHC contract
Most of the clauses of this chapter have a clear relation to warranty; these are set out in bullets below. In the contract there are more chapters in relation to the implementation of the warranty claim, like title & risk, inspection and taxes. These chapters are not included in this research; the focus here is on the warranty aspect. The following bullets will give a summary of the most important issues:

- Warranty period: 12 months;
- Starting at: signing the Protocol of Completion or a Certificate of Completion;
- Notification of defect within 15 days after it occurs;
- Total warranty period never exceeds 24 months;
- Renewing warranty: Repaired and replaced parts have an additional warranty period of 6 months with a maximum of 24 months from the start of the warranty period;
- All duties and taxes related to repairs are for the account of the client;
- IHC has the right to investigate the validation of a claim, at its own costs;
- Replaced items are owned by IHC and returned to IHC on request;
- Repair or replacement can be done elsewhere: limited liability for IHC and same budget as executed repair at IHC premises;
- IHC warranty expires immediately under specific circumstances: (see clause 13.5);
- IHC is not liable for any defect under specific circumstances: (see clause 13.6)
Findings (warranty) terms & conditions sale at IHC
The three parts of the terms and conditions applicable for IHC for the sale of a dredger are elaborated. In order to complete the comparison and to highlight the differences and similarities the most important subjects are summed up and compared in table 10. This is elaborated and summarized in the text after the table.

<table>
<thead>
<tr>
<th>Warranty period</th>
<th>IHC terms</th>
<th>VNSI terms</th>
<th>IHC contract</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>6 months</td>
<td>3 months</td>
<td>12 months</td>
</tr>
<tr>
<td>Starting date warranty</td>
<td>Ready to deliver</td>
<td>At delivery</td>
<td>At contract date</td>
</tr>
<tr>
<td>When shifts liability from IHC to Client</td>
<td>Delivery date</td>
<td>Delivery</td>
<td>-</td>
</tr>
<tr>
<td>Consequential losses</td>
<td>-</td>
<td>IHC not liable</td>
<td>-</td>
</tr>
<tr>
<td>Notification of defect</td>
<td>Yes, in 2 weeks</td>
<td>Yes, 7 days</td>
<td>Yes, in 15 days</td>
</tr>
<tr>
<td>Right to invest a claim and reclaim costs</td>
<td>-</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Repair at IHC premises</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Repair by third party</td>
<td>Yes</td>
<td>Yes, at same price</td>
<td>Yes, at same price &amp; no responsibility IHC</td>
</tr>
<tr>
<td>Cost of transport &amp; tax related to repair</td>
<td>-</td>
<td>-</td>
<td>Yes, for the Client</td>
</tr>
<tr>
<td>Repaired items return</td>
<td>-</td>
<td>-</td>
<td>Yes, on request</td>
</tr>
<tr>
<td>Warranty on repair</td>
<td>-</td>
<td>-</td>
<td>Renewing, 6 months</td>
</tr>
<tr>
<td>Clause when warranty expires</td>
<td>-</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>External delivered parts to client excl. of warranty</td>
<td>-</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>Special terms &amp; exclusion for special conditions</td>
<td>-</td>
<td>-</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 10: Differences in terms & conditions 'sale’

Concluding on terms & conditions sales at IHC
The difference between the ‘standard IHC terms’ and the ‘IHC contract’ is significant. The contract is much more extensive and also covers the wellbeing of employees and shipping responsibility of a possible repair. The VNSI terms are written for all kind of shipyards, most of them are not interested in the aftermarket, thereby most shipyards are building less complex equipment with a lower risk of failures. In table 12 the characteristics are mentioned and compared to the different used terms. When the warranty period will be extended the terms & conditions will become more important and should be checked and tuned by a juridical expert.

Interviewing different (sales) managers within IHC gave insight in the way the different terms are used in practice. The standard terms (IHC & VNSI) are added to all correspondence towards clients, with most clients a contract will be formulated in the end of the negotiation phase. If not, the standard terms are applied.

Warranty period
Remarkable are the differences in the warranty period varying from 3 months up to 6 months, where in most cases the client asks for a warranty period of 12 months. Competing companies in the Netherlands also offer a warranty period of 12 months. The difference between the warranty period of 6 and 12 months for the Beaver dredgers is a marketing aspect in form of negotiating space for the seller. In the end most Beaver dredgers
(78%) are sold with a warranty period of 12 months. This warranty contract is non-renewing; meaning that when a part of the Beaver is repaired or replaced, there is no longer any warranty valid on this specific part.

In general can be concluded that the current terms and conditions are not specified to particular parts or system components; this implies that the warranty is applicable to all parts of the dredger. If certain facts are not mentioned in the terms and conditions, the Dutch Civil Law refers to the principle of *bona fides or good faith, in so far it concerns the duty to observe reasonable social and commercial standards of normal and fair dealing*, better known as ‘reasonableness and fairness’ (*redelijkheid en billijkheid*). Since any parts exposed to dredging material will wear and tear over time, it might be that these parts need repair or replacement even within a year. Interpreting the terms and conditions combined by the Dutch Civil Law, a client cannot expect that wear and tear parts will be replaced through a warranty claim. However, this is an interpretation of what is documented, but since this is not evident from the written documentation there will always be space for discussion on these claims.

By interviewing the engineers of IHC who are dealing with the warranty claims it turns out that the parts that are subjected to wear are excluded from warranty unless a mistake is made in the production process. This is not mentioned in the term and conditions of IHC but corresponds to the ‘reasonableness and fairness’ in the Dutch Law.

### 5.2.4 Terms & conditions procurement at IHC

In the beginning of this paragraph the difference is made between the terms and conditions of sale and procurement, the sale terms having been discussed already, now the procurement terms will be discussed. A difference with the sale terms is that there is one set of general terms of purchasing of IHC applicable. These terms are used for the purchasing of parts under certain conditions. A part of the General condition of purchasing of IHC Merwede is related to the warranty aspect and can be found in appendix C1.

#### Findings General condition of purchasing of IHC

For a supplier like IHC it is really important to manage all risks. One of these risks is giving a year of warranty to the client if the agreements with sub-suppliers are not made the right way. The risk then is that IHC might be held (only) responsible for parts supplied by sub-suppliers. If the warranty period will be extended the risk will grow too. Thereby sub-suppliers are essential because they deliver around 60% of the parts of a Beaver dredger.

The current purchasing conditions are summarized below.

- The obligation to familiarize itself with the purpose of the goods and or services to be provided to company;
- Sub-supplier warrants that the part or services are: suitable for the purpose, conform to the specifications, good quality and free from defects, meet the relevant regulations, supply the agreed result, accompanied by all relevant papers;
- Any defects or non-conformity on the good within 24 months after the date of delivery or acceptance of the good shall be remedied by sub-supplier;
- Any breach of the warranties in clause 13 within 12 months from the performance of the service shall be remedied by the sub-supplier;
- Upon discovery of a defect or non-conformity the sub-supplier shall response within 48 hours on a by IHC specified location. If the nature of the defect or non-conformity is such IHC cannot reasonably expect that the sub-supplier can recover the non-conformity, than IHC is entitled to remedy the defect itself of a third party on the account of the sub-supplier;
- All costs related to the repair or replacement by sub-supplier shall be for account of the sub-supplier;
- In the event that sub-supplier fails to remedy any defect or non-conformity, or fails, IHC will be entitled to do or instruct a third party to repair or replace the defect on the account of the supplier;
- Upon replacement or repair by sub-supplier of any goods or part(s) a renewed warranty period of 24 months shall apply.
- If as a result of a defect or non-conformity supplied by sub-supplier, then IHC becomes liable. The sub-supplier shall indemnify the IHC against all claims. This clause shall apply regardless of the length of the agreed warranty term and the expiry hereof.
5.2.5 Sub-supplier analysis

For IHC all sub-suppliers are essential for the product. The legal contracting with sub-suppliers is done by the General conditions of purchasing of IHC. Out of interviews at the purchase department within IHC it can be observed that the main driver to select a sub-supplier is price. Almost all sub-suppliers will accept the IHC purchase conditions because of the power of a large company like IHC. This does not mean that these sub-suppliers automatically can comply with all requirements requested in the terms by IHC. For some sub-suppliers IHC is a large client and the possibility to deliver the parts is of great importance so they accept the prerequisites as proposed by IHC.

One sub-supplier that is not accepts the IHC purchase condition is PON Power, the only official supplier of Caterpillar engines in the Netherlands. All Beavers are equipped with a Caterpillar engine, which is seen as an advantage by the IHC Beaver clients, mainly because their worldwide network. Therefor IHC will benefit from offering caterpillar engine in an IHC Beaver. For PON Power is IHC just a customer of engines, they have the power to consider their condition valid.

Since the sub-suppliers often operate on a lower scale than IHC does, the costs of warranty claims are relatively bigger compared to the turnover of the sub-supplier. In theory this could mean that when IHC claims the warranty expenses at the sub-supplier, the sub-supplier might not be able to finance this and could go bankrupt.

This involvement with their sub-suppliers is not a priority of IHC at the moment but probably will become so in the near future, especially with the aim of forward cooperation.

In appendix C5 an overview of the suppliers of an IHC Beaver 50 is expressed relative to the cost price.

Some important facts related to the sub-suppliers to construct an IHC Beaver 50:
- A total of 69 sub-suppliers;
- 36.2% of the Cost Price (CP) is built by IHC (including the hull);
- > 80% /CP is based on 10 sub-suppliers (including 3 internal IHC suppliers);
- The warranty period of components delivered by sub-suppliers starts at the moment of delivery to IHC (not on moment of sale for entire Beaver), this is valid for all sub-suppliers except from PON power.
- Only PON Power (Caterpillar) does not accept the purchase terms of IHC (share of 21.8% /CP).

Concluding, with the intention of forward cooperation but also for the current warranty period, it is important to manage the relationship with the sub-suppliers in a proper way. As seen in the above facts there is already one sub-supplier (PON Power) that does not currently accept the purchase terms, if in the future more sub-suppliers will behave in the same way this would have important consequences for IHC.

With the aim of forward cooperation sub-suppliers and IHC become partners for a longer period, only in good cooperation between these partners the best product can be developed.

Concluding on terms & conditions procurement at IHC

Most sub-suppliers of IHC are accepting the purchasing condition of IHC, which is a good basis for forward cooperation. However; some future challenges could be:
- The price;
- Parts that are ordered by IHC prior to the start of building a ship while the warranty of the parts is expiring (meaning that when the warranty period of sub-supplier is expired, while the warranty period of the IHC contract is still valid, IHC turns up for the costs that would otherwise have been covered by the sub-supplier);
- The dredger can be on stock at the premises of IHC for a while before it is sold to the client while the warranty of the parts is expiring too.

5.2.6 Claim procedure

In the warranty policy a clause is included which describes how the client has to submit a warranty claim to IHC. To analyse how the claim is processed internally at IHC Service, the claim procedure can be found in appendix C2.
In essence the warranty claims can be handled by IHC in four different manners;
- Reject;
- Hand over to sub-supplier;
- Hand over to insurance for which IHC as a company is insured;
- Accept and finance the claim.

The first thing to notice about the flowchart of the claim procedure is that there are three stakeholders involved: (i) the client, (ii) Royal IHC and (iii) the sub-supplier. The chart starts at the moment that the client claims a nonconformity or defect at IHC. The cause of the claim is at that moment unknown but can be the failure of a component or a complete system. The client fills in a Guarantee Application Form (GAF) and sends this form towards IHC Services. However, in practice these GAF’s are not always filled in properly; engineers of IHC often experience that these forms are lacking information, or the client informs IHC in another way, not filling in the GAF at all. Then the GAF arrives at IHC Services and will be assessed by the responsible warranty engineer at IHC. At the assessment the first decision moment occurs; accept or reject the claim based on the IHC Terms and Conditions (DM1). When the claim is accepted, IHC will take the full responsibility to solve the claim.

After accepting the claim a second decision has to be made (DM2); whether to claim on the warranty of the sub-supplier or not. Component or systems delivered to IHC by a third party are often also provided with warranty from the sub-supplier for a certain period of time. For this reason it is possible for IHC to divert a warranty claim towards a sub-supplier if this is still within the warranty period of the part supplied to IHC. The sub-supplier will assess the claim from IHC. If the sub-supplier accepts the claim, he is responsible for solving the claim. If the claim is rejected by the sub-supplier the claim will come back to the warranty engineer and IHC has to solve the claim. Out of interviews it turns out that most claims are solved within IHC internally. A reason can be that the customer satisfaction is very important and that IHC therefore does not want to risk the client relation.

In the process of solving the claim the third decision moment has to be made, claiming the insurance or not (DM3). For individual claims with costs higher than the own risk IHC is insured during the warranty period. Before this decision is made, a cost estimation of the claim has to be made. Are the estimated costs lower than the own risk, than the costs are for the account of IHC. The decision to claim the insurance can affect the insurance premium in the future, therefore the costs of the claim have to be significantly higher than the own risk in order to decide to claim for the insurance.

Eventually the claim will be handled in one of the four ways and the customer will be informed, if the customer did not know yet. Warranty claims can contain relevant information about the weaknesses in the design or failures in the production process. For this purpose it is important that there is feedback going back into the organization of IHC (design- & production department) and if necessary maybe even to the relevant sub-supplier. Since 2014 all claims are registered in the Document Management System (DMS), in this system all relevant information about the ship is registered. The DMS is relatively new and the documentation for clients is also limited so the information in the DMS is also limited (input is output).

Concluding on the claim procedure
The claim procedure is working properly to solve the claim for the client. However the warranty claims contain more information than is used at the moment; therefore the feedback loop into the organisation has to be improved. Currently problems from the client are always solved in a proper way but the information that is provided by the client is too limited.
In order to align the process of handling a claim better it would be recommended that IHC has to ask the client for complete filled GAF before accepting the claim.

5.2.7 Claim analysis
Warranty claims of all ships built by IHC are registered in the Document Management System (DMS). In this system all relevant claim data about technical information and the communication between IHC and the client is stored and maintained. In appendix C3 an example of a claim from the DMS can be found. Other than the claim information also some other information about the ships can be found, such as technical information and drawings. The DMS can thus be considered as an 'electronic profile' of a ship; containing information that might be relevant for stakeholders in certain situations. When the DMS was developed the
main goal of the system was to register claims, on the one hand for IHC to build up a database and on the other hand to be able to process the claims in an easy way. Regarding the access of this DMS all engineers of IHC can overview the information that the DMS contains, a client will never have access to the DMS. However the input of data into the DMS is managed by the appointed IHC warranty engineer of a ship.

Concluding on the claim analysis
The DMS is a good program to register the claims data because the system is recently developed and is therefore very up to date. However the downside of this is that the system is only in use since 2014 and therefore not a lot of information on the claims of the ships is incorporated yet. Moreover most engineers fail to enter all detailed information in the system, since their way of working is still the same as before the introduction of the DMS.

Altogether, the system is a well-organized way to get feedback from the warranty claims back into the organization of IHC. If the system is used properly in the future and the system will built upon integrating even more information, it can contribute to the analysis of the failure behaviour of the standard Beaver dredgers. When much data is collected over multiple years it can be analysed to discover certain patterns or for instance the weakest parts/ components. Then the knowledge of engineers can be better backed up by the data delivered by the DMS, which is very important for the feedback loop to the design & production department as well.

In this chapter it can be concluded that the sub-suppliers have an important role in several processes within IHC.
5.3 Product reliability

Amongst clients the Beaver dredgers from IHC have a reputation of expensive though very reliable. Some even say, that the Beaver dredgers are “over dimensioned”. But how can it be that the data on the reliability of these products is lacking? The answer is found in the history of the IHC Beaver dredgers.

The Beavers are designed and built in the town of Sliedrecht for decades, each time a new type of ship is developed the good is innovated; making it slightly better. If faults occur repeatedly, the design will be modified. This is all done within a small team of experienced engineers where everyone knows the product well. There is a lot of experience on the design of these Beavers amongst the engineers. Since in general the engineers of IHC remain in their job for a long time they built up their expertise and the expertise remains within the company.

Until now, the operation phase has not been the focus of IHC, therefore the interest in reliability data about the operational phase is also limited. Another important factor why the data is limited is that the Beavers are working all over the world, at the moment there is not even one Beaver working in the Netherlands, this makes analysing systems in the operation phase difficult and expensive.

It cannot be concluded that the Beaver is unreliable; the reliability of the product has widespread support, it is just that the exact data is missing at this time.

To enable the understanding of the function of the IHC Beaver 50 system a System Overview is created and can be found in Appendix C4.

The theory of Murthy (2006) describes that an approach to model product failure on system level is make a Fault Three Analyses (FTA). For all modelling applies the rule of ‘input is output’ is applicable. In this case that means when there is data available about the operation of the Beaver dredger, the modelling could lead to a theoretical approach of the reliability of a Beaver dredger. Unfortunately, the data available in the IST situation is not sufficient enough to make a proper Fault Three analyses.

Conclusion on the product reliability

When considering the warranty period of one-year and relating this to the product reliability; the only requirement is that all systems and components function. For this reason the reliability of all individual systems and components is important, unfortunately related data is not available at IHC. Out of system overview and investigation in the dependency of the systems can be concluded that there is no redundancy and that all systems and components have to function during the warranty period.
5.4 Product usage

The company Royal IHC broad customer base includes dredging operators, oil and gas corporations, offshore contractors and government authorities (IHC website).

The client base of IHC is known, but the exact usage of the product and the way it behaves is unknown. In the IST situation there is only a minimal feedback loop from the usage of the product to the supplier.

To approach the product usage three profiles for the clients are created. These profiles are based on the interviews and information on websites of clients that are currently in the database of IHC. To be able to determine the product usage scenarios the following components that determine the usage are specified.

1. Usage mode;
2. Usage intensity;
3. Operating environment;
4. Operator skills;
5. Maintenance.

5.4.1 Usage mode

The usage mode describes the functions of the product. The IHC Beaver 50 is a Cutter Suction Dredger (CSD) and in the introduction towards the case study, the IHC Beaver 50 is explained.

In short the two basic principles of the IHC Beaver CSD are:

(i) Cutting: The IHC Beaver uses a cutter section on the end of the pipe to loosen different types of soil. The cutter section can vary and is depended on the client's demands and the area the dredger will be used.

(ii) Suction: The other mode of the IHC Beaver is the suction section. Soil that is loosened by the cutter can be suctioned for transport to another location.

When using the IHC Beaver both modes are used at the same time.

5.4.2 Usage intensity

The intensity in which the client uses the IHC Beaver is dependent on the type of client and project. An IHC Beaver is designed to do an average of 2,500 operating hours per year and to last thirty years.

When the Beaver is used intensively (more than 2,500 operating hours per year) some of the parts, which are dependent on the usage intensity, will wear down faster. Those parts should be replaced in an earlier stage than normal.

The usage intensity is also dependent on the purpose and the way in which the IHC beaver is used. Three common purposes can be distinguished:

(i) Governmental use: A government or a port authority will use the Beaver when needed. The usage intensity can generally be qualified as low intensity of usage.

(ii) Commercial use: A commercial company will use the Beaver as frequent as possible in order to achieve a short return on their investment. Examples of these companies are Boskalis and Van Oord. The commercial use can be qualified as average/normal use.

(iii) Mining: Beavers can also be used for mining purposes. When Beavers are used for mining the Beaver is used intensively and constantly to produce as much as possible. The use for mining can be qualified as high intensity use.

5.4.3 Operating environment

The usage intensity and the operating environment determine the wear rate of the parts of the Beaver. The type of soil determines the operating environment. A Beaver is designed to progress silt, sand and grid. There is a rule of thumb applicable to the wear of the Beaver: The coarser the soil, the higher the wear. In the dredging industry the Particles Size Distribution (PSD) defines the soil.
When quantifying the type of soil, three impact levels on the Beaver can be distinguished:

(i) Fine soil, which has the least influence on the wear of the Beaver.
(ii) Medium Soil, which has average influence on the wear of the Beaver.
(iii) Coarse soil, which has the most influence on the wear of the Beaver.

5.4.4 Operator skills

For the design of the operating system of the IHC Beaver a low level of education and experience of the operator of the client is taken into account. The operation system is simple, manuals and instructions are provided at the sale.

In practice it turns out that a more experienced operator is able to generate more volume and consistent production. The operating level is of influence on the wear rate of the IHC Beaver.

To improve the level of operation quality, IHC offers education and training programs through the Training Institute for Dredging (TID). Some of the trainings that TID offers are: operator training and simulator training.

The operator skills can be divided into three levels:

(i) *Experienced and trained*. A trained and experienced operator knows the way the Beaver operates and will notice wear and tears in an early stage. Because of his experience the Beaver will be operated as it is intended, which will also lead to less wear.

(ii) *Inexperienced and trained*. An inexperienced but trained operator will operate the Beaver as intended, but will not notice differences that can indicate wear and tear.

(iii) *Inexperienced and untrained*. Inexperienced and untrained operators will use the Beaver in the way they expect it should which can vary from the way it was intended to. This can cause unnecessary damages and wear. Also they will not notice differences that can indicate tear.

5.4.5 Maintenance

Royal IHC rarely executes the maintenance of the IHC Beavers, which is why it is complicated to give an estimation of the influence of the maintenance on the product reliability. The client is responsible for the maintenance of the Beaver. The client is free to choose where and how the maintenance is performed.

IHC offers the possibility to offer spare parts for the maintenance. A search through the database shows that only a small percentage of the clients return to IHC for the spare parts service.

This can be explained for three reasons:

(i) The Beaver is not in use or used only occasionally, which results in a minimum of wear;
(ii) The client buys parts at local dealers or lets the parts being reproduced;
(iii) The client buys the parts directly at the supplier of the spare parts (such as Caterpillar).

To quantify the frequency of the maintenance of the Beaver, the following levels are defined:

(i) *Preventive maintenance*. A client is able to choose to send its Beaver for regular maintenance check-ups to prevent failure of parts and eventually loss of production.

(ii) *Corrective maintenance*. A client is also able to choose to correct failures when they occur, by replacing or fixing the worn down part.

(iii) *No maintenance*. It is possible that a client chooses to no maintenance but to fix the failures that occur itself with no help of a specialised company.

5.4.6 Usage scenarios

There is limited data available on the usage of the IHC Beavers. The information that is available is based on experience from the technicians of IHC, which were interviewed for this research.

The five components of product usage as described above can be divided into two groups, the first is the influence of the client on the product and the second is the usage intensity.
The clients’ influence combines the way the product is operated and the way the maintenance is performed, so it is the way the client is taking care of the product. The clients’ influence can also be described as the *Clients’ level of usage quality*. By adding up the different components that are a part of the Clients’ level of usage quality three scenarios are formed. To decide which scenario is applicable the following tables can be used.

<table>
<thead>
<tr>
<th>Scores per level</th>
<th>4. Operating skills</th>
<th>5. Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Experienced and trained</td>
<td>Preventive maintenance</td>
</tr>
<tr>
<td>2</td>
<td>Inexperienced and trained</td>
<td>Corrective maintenance</td>
</tr>
<tr>
<td>1</td>
<td>Inexperienced and untrained</td>
<td>No maintenance</td>
</tr>
</tbody>
</table>

*Table 11: Clients’ level of usage quality*

When the level of operating skill and the maintenance level is known of the client the score can be determined by adding up the scores. For instance a client applies preventive maintenance (score 1) but uses inexperienced and untrained operators (score 3) the total score is 4.

The next step is to see which scenario is applicable by using the table below.

<table>
<thead>
<tr>
<th>Total score</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clients’ level of usage quality</td>
<td>Low</td>
<td>Average</td>
<td>High</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 12: Score table of clients’ level of usage quality*

This table can be used to quantify the client level of usage quality in the future.

The second group is the *level of the usage intensity*. The level of usage intensity is influenced by the components: usage intensity and the operating environment.

<table>
<thead>
<tr>
<th>Scores per level</th>
<th>2. Usage intensity</th>
<th>3. Operating environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Governmental – low intensity</td>
<td>Fine soil</td>
</tr>
<tr>
<td>2</td>
<td>Commercial – average intensity</td>
<td>Medium soil</td>
</tr>
<tr>
<td>3</td>
<td>Mining – High intensity</td>
<td>Coarse soil</td>
</tr>
</tbody>
</table>

*Table 13: Clients’ level of usage intensity*

The next step is to see which scenario is applicable for the level of usage intensity using the table below.

<table>
<thead>
<tr>
<th>Total score</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level of usage intensity</td>
<td>Low</td>
<td>Average</td>
<td>High</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 14: Score table of clients’ level of usage intensity*

To give an indication of the usage scenario the scores of the different tables can be summed up. This way the scenarios between different clients can be compared. This is merely a method to compare usage scenarios against other clients, this is only an estimation since the numbers are not informative on their own.

**Concluding on the product usage**

There is limited information available about the clients of the IHC Beaver dredgers. The information that is available is inconsistent and incomplete. With the information available and with the help of interviews the product usage is approached using the two groups that influence the product usage; (i) the clients’ level of usage quality and (ii) the level of usage intensity. The first is influenced by the care of the client, the second by the usage intensity and the environment. By levelling the components it is possible to determine three user scenarios: low, average and high.

This method could be used by IHC to quantify future clients in order to predict the product usage, although it is a very theoretical approach and thus has it is limitations when put in practice.
5.5 Warranty Costs
The warranty costs are dependent of the three variables described in the model of Murthy (2006); (i) warranty policy, (ii) product reliability and (iii) product usage. Except from the warranty policy the other two variables are unknown. Furthermore; of these three variables only the warranty policy and the product reliability are fixed over time; the product usage can vary per client and is therefore variable. Considered that the product usage (and thus the influence of the client) has a big effect on the warranty costs it is expected that the resulting warranty costs can differ hugely between different clients.

By analysing the warranty costs of the past five years it is possible to compare the real costs with the estimated warranty budget. Furthermore this kind of data allows to analyse the increases and decreases are interesting to research since they might indicate certain changes that influence the warranty costs.

5.5.1 Warranty cost analysis
Warranty costs are a result of a claim made by a client, as is described in chapter 5.2.7. The warranty claims can be handled by IHC in four different manners;
■ Reject;
■ Hand over to sub-supplier;
■ Hand over to insurance;
■ Accept and finance the claim.

Analysing the warranty costs of IHC over a previous period of time requires a lot of data. But there is no data on how many claims are rejected or handed over to sub-suppliers of IHC. These claims or costs are not registered and unfortunately they cannot be taken into account for this analysis. Another given option is that the insurance handles the claim; over the period of the past five years this is done several times but the details on these settlements are missing. The data for when the claims are handled by the insurance is also missing, therefore the analysis based on data can only be made on those claims accepted and handled by IHC. The data available on these accepted claims is only known on the level of the claims made, how these costs are divided over material costs, working hours and other aspects is also not registered. Also the information about which part or component the claim is made is too limited to make any conclusions. This, unfortunately, makes it impossible to analyse how the costs for these claims are divided. At the moment IHC is collecting important data to build-up a database.

The budget reserved for warranty costs by IHC internally is 0,6% of the sales price. Not all Beavers are sold with a one-year warranty period, some are sold with the standard period of 6 months (an estimated 22% of the Beavers). The extended 6 months of the standard period are used by IHC to convince a client of sales, but the budget for warranty costs remains the same. Over the past five years the warranty costs in percentage per year were 1,06% based on the accountancy of IHC. It is remarkable to notice that there are extreme highs and lows in the costs. Clients who do not make any claims cause the lows. This can either be explained by the fact that they do not use the ship (or not frequently) or to the fact that they are not used to make any claims and instead solve any problem themselves. The highs can be explained either by the introduction of new types of Beavers or new techniques that might have some problems in the early stages of use, or by clients who make a lot of claims.

Concluding on the warranty cost analysis
An analysis of the warranty costs over the past five years show that they are on average 1,06% of the sales price, this means that the current estimated budget of 0,6% of the sales prices is not sufficient. It is necessary to gather more data on how the claims are handled and how the warranty costs are build up in order to be able to say how these costs can be reduced. The expansion of the warranty costs is caused by a few claims with relatively high costs. These claims are in some cases related to the introduction of a new Beaver type or the insufficient quality of the delivered part by the sub-supplier. Avoiding these peaks in the warranty costs is therefore the best starting point in reducing the warranty costs. This can be done by making a different budget available for the introduction of new types of Beavers, which frequently cause warranty claims since these slight innovations can result in problems in the first few months of use. Another option to reduce the warranty costs is by making better agreements with those sub-suppliers of IHC that supply parts or components that frequently are the cause of a warranty claim by a client.
5.6 Conclusion IST situation

To analyse the IST situation of warranty on dredgers the Beaver 50 of Royal IHC is used for a single case study. This chapter about the IST situation was introduced by the theoretical model of Murthy, that describes how the warranty policy, the product reliability and the product usage influence the warranty costs. Concluding on the IST situation the main findings on these influencers will first be summarized and then be described in the assessment table.

Warranty policy

For IHC there are two important groups of stakeholders; the clients and the sub-suppliers. For both stakeholder groups terms and conditions are drafted with the purpose of sale of products (from IHC to the client) and the procurement of parts (from IHC to the sub-suppliers).

For the sale of products it is noticed that the difference between the ‘standard IHC terms’ and the ‘IHC contract’ is significant. When the warranty period will be extended the terms & conditions will become more important and should be checked and tuned by a juridical expert.

For the procurement of parts it is important to note that the role of the sub-suppliers is essential because they deliver over 60% of the parts of the Beaver dredger. How agreements are made with sub-suppliers on the warranty period of the supplied parts is therefore essential when IHC has the intention to apply forward cooperation.

Warranty claims can be handled by IHC in four different manners; (i) reject, (ii) hand over to sub-supplier, (iii) hand over to insurance or (iv) accept and finance the claim. The claim procedure works sufficiently to solve the claim for the client. However the warranty claims contain more information than is used at the moment; therefore the feedback loop into the organisation has to be improved.

Warranty claims of all ships built by IHC are registered in the Document Management System. If this system is used properly and the system will build upon integrating even more information, it can contribute to the analysis of the failure behaviour of the standard Beaver dredgers in the future.

Product reliability

Amongst clients, dredgers from IHC have a reputation of being expensive though very reliable; the reliability of the product has widespread support. Also the engineers have a lot of experience on the design of these Beavers and have built up their experiences over years, IHC certainly has a lot of expertise in this area. However, data on the product reliability is missing at this time. When aiming on forward cooperation it would be wise to get better registration on the product reliability.

Product usage

How the operators are using the Beaver 50 varies hugely between different clients. This is dependent of the usage mode, the usage intensity, the operating environment, the operator skills and the maintenance. The product usage is estimated or approached by creating two user profiles; with low, average and high impact on the product performance.

Warranty costs

Warranty costs are estimated at 0.6% of sales price, however the accountancy of the past five years show that the warranty costs turned out to be 1.06% of the sales price. This shows that there is a large gap in how the warranty costs are currently estimated and how they turn out to be in practice.
To summarize the IST situation, the assessment table will be filled in. In table 13 can be seen how the assessment table looks for the IST situation.

<table>
<thead>
<tr>
<th>Assessment points:</th>
<th>Fixed / Variable</th>
<th>Known / Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who’s in control?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A - Warranty policy</td>
<td>Supplier</td>
<td>Fixed</td>
</tr>
<tr>
<td>B - Product Reliability</td>
<td>Supplier</td>
<td>Fixed</td>
</tr>
<tr>
<td>C - Product Usage</td>
<td>Customer</td>
<td>Variable</td>
</tr>
<tr>
<td>D - Warranty Costs</td>
<td>Supplier &amp; Customer</td>
<td>Variable</td>
</tr>
</tbody>
</table>

Table 15: combination of the simplified characterization model and the current situation at IHC
6. SOLL situation

In the previous chapter the current situation (IST) for the case is assessed according to the theory of Murthy (2006) and the assessment table. As concluded in the literature research extended warranty has the best characteristics to achieve forward cooperation for a standard dredger within Royal IHC. Based on this conclusion the scenario for the SOLL situation is set to provide extended warranty with a time-frame of five years.

The next step is to define the characteristics that are needed for the implementation of forward cooperation. The research goal is to achieve forward cooperation between the supplier (IHC) and client, therefore in the perfect situation the supplier and the client both benefit from the extended warranty.

In this chapter the characteristics of the simplified model of Murthy are described for the perfect situation of extended warranty. This description is based on the information that is known from the analysis of the IST situation, interviews within IHC, the literature and results from the benchmark analysis.

6.1 The benchmark analysis

Royal IHC builds equipment especially for the dredging and offshore sector. More generally the dredgers can also be considered as a capital good, for which it can be compared with other capital goods. By comparing to other capital goods that are using forward cooperation to extend their warranty some lessons from other companies can be learned. In order to explore how other companies (in other industries) apply forward cooperation a benchmarking study is conducted. A complete overview of this study and the results can be found in appendix D.

Benchmark companies

The characteristics of the products of the benchmark companies are: standard type machines; large circulation; made to handle soil; mobile machinery; no fixed workplace; extensive range of warranty and service packages and variety from different countries. The benchmark companies are mostly suppliers of excavators and are selected on offering extended warranty. The companies and their products used in the benchmarking are: Atlas Copco (Compressors, generators, paver, rollers), Hitachi (excavators, wheel loaders, dump trucks) Kobelco (excavators) Komatsu (excavators, bulldozers, dump trucks, loaders), DOOSAN (excavators, wheel loaders, dump trucks), John Deere (Tractors, forage equipment, excavators), Caterpillar Marine (engines & generators).

Conclusions benchmarking:

- The base warranty offered by the benchmark companies is mostly limited on time (1D), sometimes on time and usage (2D);
- All suppliers offer extended warranty. The extended warranty is mostly limited on 2D and half of the suppliers is performing additional inspections to control the product performance;
- The combination between maintenance and (extended) warranty is offered rarely;
- Maintenance as a service is not commonly offered by these suppliers;
- The owner of the equipment is responsible for all maintenance, but some warranty providers require that regular interval maintenance is executed at an authorized dealer;
- All suppliers prescribe the use of original parts;
- Almost all suppliers specify or exclude parts or systems for (extended) warranty and specify policies for specific types of equipment;
- Extended warranty can be subscripted till the end of the base warranty period.
6.2 The characteristic of the SOLL situation
The characteristics of the perfect situation, the offering of extended warranty for five years, are described below. As mentioned in the introduction, the perfect situation is achieved when the supplier and the client benefit from the extended warranty. When translating benefits into policies and prices it means that it has to be fair to both parties.

A – Warranty policies
In the conclusions of the benchmark analysis some implications for the warranty policies for the perfect situation are suggested, these are the following:

- The policies are two-dimensional, limited on time and usage.
- There should be a clear description in the policies on the responsibilities for the client and the supplier, in example the daily maintenance is the responsibility of the client, the regular interval maintenance should be executed by an authorized dealer suggested by the supplier.
- The policies contain a specification for the inclusion or exclusion of parts of the equipment. This is also to be clear about the responsibilities of the supplier and the client.

In the perfect situation when the extended warranty is offered to the client the policies need to be legally sustained. This is beyond the scope of this research, however some suggestions could be made based on the analyses of the IST situation.

In order to limit the risks for Royal IHC it is critical that there is a clear demarcation of the responsibilities for IHC and the client. However, it is also important for IHC that the demarcation is also clear in the relationship with the sub-suppliers.

When looking at the assessment table the policy for the extended warranty will be classified as known. In the perfect situation the policy will be written and checked by a legal expert.

Furthermore, the costs of repair or replacement would be known in advance in order to make sure the risks are divided equally amongst client, IHC and the sub-suppliers.

Concluding from the IST analysis and the benchmark the extended warranty policy should meet the following standard requirements for each type of equipment;

- Restrictions on product usage and usage duration (2D);
- A clear set demarcation of the responsibilities for the client, the sub-suppliers and IHC regarding the use, maintenance and the repairs;
- A clear demarcation on whether parts or components are included or excluded in the warranty.

B – Product reliability
How reliable the product is based on test data, failure data and the failure behaviour. If this is all known it is possible to make an estimation of the product reliability. In theory it would be possible to model the entire product without considering the influence of the product usage. This model would help to make the entire system more reliable and to reconsider the function of those parts with the highest risk. These parts could be excluded from the warranty policy or given more budget in the design or building phase to improve these parts.

For IHC this would imply that all data on failure would be known and that the production quality is consistent (or fixed), both from IHC as well as from the sub-suppliers.

As analysed in the IST situation the IHC Beaver data on the product reliability is limited. In the perfect SOLL situation the data of the product will be described as known in the assessment table.

For the perfect SOLL situation the following on product reliability data should be known for the supplier:

- Failure documentation (failure data & failure behaviour) per system & component;
- System failure relations between the components.

C – Product usage
From the benchmark is concluded that the daily maintenance often is the responsibility of the client as the client is influencing the product performance with its usage.

As described in the analyses of the IST situation the product usage is influenced by the operations of the client. In the perfect SOLL situation the influence of the client on the product performance is forced in the right way when possible and when this is not possible the product usage will be checked or verified. This should result in
minimizing the potential damage of the product usage to the product performance of those products or parts that are included in the warranty. By steering the influence of the client it is meant that the client or the operator should also be guided in what the optimal maintenance of the product is, since it cannot be assumed that this is known with the customer in advance. A suggestion is that the clients receive a maintenance manual provided by IHC and are trained by IHC to optimize the potential of the dredging equipment. This could prevent unusual wear caused by wrong usage of the equipment.

Ultimately the supplier has the expertise on what should be the best for maintaining the dredging equipment and the operators are qualified. This was concluded in the benchmark, thereby the quality of the product will remain optimal with the usage of original parts.

For this reason, it is necessary that there is guidance for maintenance and a set of expectations for the client. Only by managing these expectations the influence of the product usage can be manageable for the supplier (IHC). IHC can set certain rules to the client on the product usage in order to manage the risks of product usage. In order to know whether these rules are being followed it would be necessary to verify this.

In the ideal SOLL situation the operator or client would follow these guidelines on product usage:

- Maintain the product as prescribed by the supplier;
- Use of the original parts only;
- Employ personnel that meet the minimal qualification skills required;
- Use the product only for purposes where it is designed for.

**D – Warranty costs**
The above elements all influence the warranty costs. The goal of applying forward cooperation for the supplier of dredging equipment is to achieve a position in which the supplier and the client become partners in cooperation on the long term. The costs of warranty have to be acceptable for the client in order for the client to actually purchase the warranty and consider the warranty to be valuable; ‘value for money’. Especially in a niche market such as the dredging sector this is important. For the supplier the warranty costs need to cover the expenses and include a reasonable margin on these costs to ensure profit.

In the perfect SOLL situation the warranty costs will meet the following requirements:

- Fixed costs need to be covered (material, labour, stay, transport etc.);
- An acceptable margin on the costs (5-10%);
- The client needs to be satisfied with the offered price for the extended warranty.

**Assessment table**
Summarizing all these elements of the ideal SOLL situation into the assessment table is shown in table 3. That many of these columns are now indicated in green is not a coincidence; it is created for the most ideal situation.

<table>
<thead>
<tr>
<th>Assessment points:</th>
<th>Who’s in control?</th>
<th>Fixed / Variable</th>
<th>Known / Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>A - Warranty policy</td>
<td>Supplier</td>
<td>Fixed</td>
<td>Known</td>
</tr>
<tr>
<td>B - Product Reliability</td>
<td>Supplier</td>
<td>Fixed</td>
<td>Known</td>
</tr>
<tr>
<td>C - Product Usage</td>
<td>Customer</td>
<td>Variable (Manageable)</td>
<td>Known</td>
</tr>
<tr>
<td>D - Warranty costs</td>
<td>Supplier &amp; Customer</td>
<td>Variable (Manageable)</td>
<td>Known</td>
</tr>
</tbody>
</table>

Table 16: SOLL situation for extended warranty (SOLL scenario 2; the perfect situation)
6.3 Conclusion SOLL situation

In this chapter the perfect SOLL situation is described based on the analysis of the IST situation, interviews within IHC, the literature and results from the benchmark analysis. The requirements for this perfect SOLL situation are summarized in Table 17.

<table>
<thead>
<tr>
<th>Requirements for the perfect SOLL condition</th>
<th>A - Warranty policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Restrictions on product usage and usage duration (2D);</td>
<td>• Failure documentation (failure data &amp; failure behaviour) per system &amp; component;</td>
</tr>
<tr>
<td>• A clear set demarcation of the responsibilities for the client, the suppliers and IHC regarding the use, maintenance and the repairs;</td>
<td>• System failure relations between the components.</td>
</tr>
<tr>
<td>• A clear demarcation on whether parts or components are included or excluded in the warranty.</td>
<td></td>
</tr>
<tr>
<td>B - Product Reliability</td>
<td>• Maintain the product as prescribed by the supplier;</td>
</tr>
<tr>
<td></td>
<td>• Use of the original parts only;</td>
</tr>
<tr>
<td></td>
<td>• Employ personnel that meet the minimal qualification skills required;</td>
</tr>
<tr>
<td></td>
<td>• Use the product only for purposes where it is designed for.</td>
</tr>
<tr>
<td>C - Product Usage</td>
<td>• Fixed costs need to be covered (material, labour, stay, transport etc.);</td>
</tr>
<tr>
<td></td>
<td>• An acceptable margin on the costs (5-10%);</td>
</tr>
<tr>
<td></td>
<td>• The client needs to be satisfied with the offered price for the extended warranty.</td>
</tr>
<tr>
<td>D – Warranty costs</td>
<td></td>
</tr>
</tbody>
</table>

Table 17: Requirements for the perfect SOLL situation

Now that the IST and the SOLL situation are defined, the next chapter will elaborate on the GAP analysis; what is missing in the current conditions to achieve the conditions of the SOLL situation? After the GAP analysis a method will be developed to achieve the SOLL situation. This method will be useful for applying extended warranty in the pre-launch stage.
7. GAP analysis
The GAP analysis describes the difference between the IST and SOLL. It describes the differences between the characteristics in the current situation and the characteristics in the situation with forward cooperation. However, to be able to compare the IST and the SOLL situation the timeframe needs to be equalized. This results in an intermediate step that needs to be made, the IST situation needs to be described when extended to five years. After this step the GAP analysis is conducted.

7.1 IST and SOLL situation
When comparing the IST and the SOLL situation as described in the previous two chapters the first action is to compare the dimensions. The IST situation is the base warranty where the warranty is limited by the dimension of time; one year. The perfect SOLL situation is limited by the dimension of time and usage. The timeframes for the IST and the SOLL situation are different. When trying to compare the characteristic of for instance the warranty policy, there is a mismatch in timeframes which results in an unequal comparison.

<table>
<thead>
<tr>
<th>Dimension time:</th>
<th>Base warranty:</th>
<th>Extended warranty:</th>
</tr>
</thead>
<tbody>
<tr>
<td>One year</td>
<td>IST situation</td>
<td>Option: SOLL 1-year</td>
</tr>
<tr>
<td>Five years</td>
<td>→ Option: IST 5-years</td>
<td>SOLL situation</td>
</tr>
</tbody>
</table>

Table 18: Timeframe comparison

In order to make a comparison between the IST and the SOLL situation the dimensions have to be the same. To be able to do this the dimension of the IST or the SOLL situation needs to be adjusted. Since the research is about achieving forward cooperation the IST situation will be transformed from a one-year dimension to a five-year dimension. The final GAP analysis will be made between the IST transformed to five-years warranty and the SOLL situation.

7.2 IST 5 years
Changing the timeframe of the IST situation from one to five years will have implications for the characteristics that influence the warranty costs. As described in the chapters 5 and 6, the description of the IST five-year situation will be done with the help of the characteristics of the simplified model of Murthy. The results are directly translated into the assessment table at the end of this paragraph.

A – Warranty policies
When extending the contract period, it is unknown what the effect is on the current warranty policies of Royal IHC. The current warranty policies are based on a contract period of one-year warranty. The warranty policy is designed to support the product in the first year of usage and to enable the supplier to fix production failures. When the contract period is extended the influence of the client with the usage of the product will increase. The policies are not suited to cope with this change of influence. The chance on warranty claims will increase and it is complicated to predict to what extent this will happen.

B – Product reliability
The product reliability is fixed but unknown. Within the organization of Royal IHC there is experience with the product with one-year warranty. There is a lack of information and experience with the reliability of the product after the first year of warranty.

C – Product usage
The conclusion of the product usage in the IST situation was unknown and variable. In the extended warranty situation, the organization does not know more about the usage of the product on the long term. The conclusion of this variable is unknown and variable.

D – Warranty costs
The warranty costs are dependent on the three mentioned variables. The conclusions of these variables are mostly unknown and variable, this relates directly to the warranty costs.
The warranty costs have to cover the uncertainty of all the variables. If all the variables are unknown, there are lots of uncertainties and so the warranty costs will be high too in order to create additional slack in the budget.

**Conclusion:**
In the assessment table below, the IST five-year is assessed. Compared to the IST situation with base-warranty it can be concluded that several uncertainties arise when extending the warranty with 5 years. The result of these uncertainties is that the usage and the reliability of the product cannot be predicted. This is a high risk for the supplier that will be translated in high warranty costs.

<table>
<thead>
<tr>
<th>Assessment points:</th>
<th>Who's in control?</th>
<th>Fixed / Variable</th>
<th>Known / Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>A - Warranty policy</td>
<td>Supplier</td>
<td>Variable</td>
<td>Unknown</td>
</tr>
<tr>
<td>B - Product Reliability</td>
<td>Supplier</td>
<td>Fixed</td>
<td>Unknown</td>
</tr>
<tr>
<td>C - Product Usage</td>
<td>Customer</td>
<td>Variable</td>
<td>Unknown</td>
</tr>
<tr>
<td>D - Warranty Costs</td>
<td>Supplier &amp; Customer</td>
<td>Variable</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

Table 19: IST situation extended towards 5-year warranty (SOLL scenario 1: IST 5-years)
7.3 GAP analysis

Figure 16 shows which steps need to be taken in order to conduct the GAP analysis. It shows that the IST situation as described in chapter 5 is translated into an IST five-year situation in order to compare the two situations. The GAP analysis compares the SOLL situation and the IST five-year situation and describes the differences (the gap).

![Figure 16: Steps towards the GAP analysis](image)

**Pre- vs. post-launch stage**

The analysis of the IST five-year situation and the perfect SOLL situation are both conducted in the post-launch stage, as a consequence this GAP analysis will also be conducted in the post-launch stage.

By describing the difference (GAP) between the two situations a method can be made on how to bridge the GAP. This will be executed in the following chapter, chapter 8. The method will describe how the supplier of dredging equipment can achieve forward cooperation by offering warranty for a duration of 5 years, as this is a new service it will have to be analysed in the pre-launch stage. To make this switch from post-launch to pre-launch a new framework needs to be made, the base for this framework will be the simplified model of Murthy (2006) as described in the literature chapter. The simplified model of Murthy (2006) evaluates the warranty costs, but it does not describe how the warranty costs can be defined when the current base warranty is transformed into extended warranty. That is why it is important that the GAP analysis is performed and the IST and SOLL are compared to set up the framework for a supplier of dredging equipment that wants to achieve forward cooperation.
The method that is used to analyse the GAP is the assessment table from the simplified model of Murthy (2006). This is the same method as used in the IST and SOLL analysis.

A. Warranty policies
The warranty policies for five-years of warranty are now unknown and these need to be known in order to achieve SOLL situation. To eliminate this difference a warranty policy that is applicable for a duration of five-years needs to be developed. There are several optional policies that are described in appendix B.

B. Product reliability
The product performance is defined by; (i) the product reliability (quality of materials/ sub-suppliers, etc.) and by (ii) product usage of the client. At this moment it is unknown what the product reliability is. When the warranty duration will be extended the chance that a system, part or component will fail or reaches the end of the product life cycle will increase too. Therefore, it is very important to gain more knowledge on the product reliability. Determining the product reliability is not only necessary to achieve the perfect SOLL situation, but also to get better understanding of the IST situation.

C. Product usage
In the current situation it is almost completely unknown how the client uses the IHC Beaver dredgers. Moreover, there are great variations in how different clients operate their dredgers. In the SOLL situation this must be known because the warranty duration increases and therefore the impact of the product usage will grow (exponentially) too. The variation in the expertise of operating the dredgers in the right way will always exist, however; there is a challenge for IHC to reduce this variation to a minimal by training the operators. The risk for IHC on wrong product usage by operators could then be minimized by these trainings, or by excluding those clients from extended warranty whose operators have not the right level of expertise. These sorts of preventive measures to control the product usage should be described in the warranty policy.

D. Warranty costs
For the current warranty period of one-year the warranty costs are known and the reserved budget that is based on the costs of previous years. If warranty duration will be extended to five-years and there is no comparison to previous terms that long, the costs will thus be unknown. The costs will depend on all the above listed variables.

7.4 Conclusion GAP analysis
The difference between the current situation and the SOLL situation is that there are too many unknown variables involved. For the current situation these variables are partly manageable because these were developed over a long time span and the supplier can still rely on the expertise within the one-year warranty period. For the SOLL situation this expertise and knowledge however is lacking! IHC has not enough knowledge or data on the behaviour of the IHC beavers over a longer period of time than only the first year after introduction. If IHC wants to realize forward cooperation, more knowledge and more data will be necessary.

The required actions of the supplier on the influencers of warranty costs that are found in this GAP analysis are summarized in the following table 20.

<table>
<thead>
<tr>
<th>Main actions for supplier</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Warranty policy</td>
<td>➢ Develop a new warranty policy for extended warranty for 5 years.</td>
</tr>
<tr>
<td>B. Product Reliability</td>
<td>➢ Conduct a research into the product reliability of (the type of IHC Beaver) dredgers.</td>
</tr>
<tr>
<td>C. Product usage</td>
<td>➢ Develop a method to control the usage of the IHC Beaver to reduce the risk of intensive or improper use.</td>
</tr>
<tr>
<td>D. Warranty costs</td>
<td>➢ Develop a method to determine the warranty costs!</td>
</tr>
</tbody>
</table>

Table 20: Actions for the supplier
The above reasoning leads to the following roadmap for this research; *Develop a structure were the variables 'product reliability' and 'product usage' determine the warranty costs and where the 'warranty policy' is the last variable to define the definitive 'warranty costs'. Thereby the 'warranty policies' should also influence the 'product usage'*. 

**Assessment table**

Once again referring to the assessment table, the following findings of the GAP analysis are summarized in this table 21.

<table>
<thead>
<tr>
<th>Variables:</th>
<th>Who's in control?</th>
<th>Fixed / Variable</th>
<th>Known / Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>A - Warranty policy</td>
<td>Supplier</td>
<td>Variable → Fixed</td>
<td>Unknown → Known</td>
</tr>
<tr>
<td>B - Product Reliability</td>
<td>Supplier</td>
<td>Fixed</td>
<td>Unknown → Known</td>
</tr>
<tr>
<td>C - Product Usage</td>
<td>Customer</td>
<td>Variable → Manageable</td>
<td>Unknown → Known</td>
</tr>
<tr>
<td>D - Warranty Costs</td>
<td>Supplier &amp; Customer</td>
<td>Variable → Manageable</td>
<td>Unknown → Known</td>
</tr>
</tbody>
</table>
8. Developing a framework

8.1 The Framework

The current situation (IST) and the ideal situation (SOLL) are defined, the GAP is described in the previous chapter, the next step is to develop a framework that could be applied by dredging equipment suppliers to achieve forward cooperation.

The analysis of the IST, SOLL and the GAP is structured with the simplified model of Murthy. This simplified model is meant to analyse products in the post-launch stage. As already described in the previous chapter the IST situation is defined in the post-launch stage but in the SOLL situation it should take place in the pre-launch stage because a new service is developed. This has an effect on the simplified model for warranty costs of Murthy. In this chapter the simplified model of Murthy will be used as a basis for the framework for the dredging equipment supplier to achieve forward cooperation in the pre-launch stage. The transformations from the model of Murthy into the framework that can be used for forward cooperation will now be listed step by step.

8.1.1 - From supplier to integrator

IHC is responsible for the design, the development and the construction of the IHC Beaver. IHC relies on a lot of sub-suppliers for parts of the IHC Beaver. The analysis of the current situation showed that, more than half of the parts needed in the IHC Beaver are delivered by sub-suppliers. This makes IHC very dependent on the sub-suppliers for the delivery time, the quality of the parts and the price.

The simplified model of Murthy (figure 17) is made for the supplier of the product. Murthy calls this supplier the manufacturer; because it is considered the company that ‘manufactures’ the entire product. Since IHC however has not only the role of manufacturer, considered that they do not make all the parts themselves but depend on sub-suppliers, this term is not very appropriate. The role, and thus the responsibilities of IHC, is bigger than that of a manufacturer alone. Therefore the term ‘integrator’ is more appropriate; indicating that they do not only ‘manufacture’ the ship but are more of an ‘integrator’ with an important connection to their sub-suppliers.

![Diagram](image)

Figure 17: From supplier to integrator

8.1.2 - Backward cooperation to achieve forward cooperation

When IHC wants to offer extended warranty to its clients, the financial risks will increase. This is the direct result from the fact that there is a lack of information about the behaviour of the client and the IHC Beaver in the lifetime. To reduce the financial risk of the offering of extended warranty IHC has the option to use any or multiple of the following three methods:

(i) Make agreements with the sub-suppliers;
(ii) Insure the financial risk at an external organisation;
(iii) Reserve budget within the company.

The third method, the reservation of budget is a simple solution for IHC to manage the warranty costs. The negative side of reserving budget within the company to cover risks is that the reserved budget could not be
used for other purposes. The costs of the IHC products will have to include a percentage for the reserve, this will lead into a higher price for the client or lower margins for IHC.

The second method is to insure the financial risk at an external company. The insurance needs to cover possible claims by the clients. As IHC has little information about the claim behaviour of their clients and the usage this will result in a high insurance fee. It is also known within IHC that insurance companies are reluctant to insure this type of service. This high fee will result in: higher costs for the client; or lower margins for IHC.

Therefore the first option is considered the best option; to cooperate with the sub-suppliers in the whole supply chain. To do so the relationship between the supplier and sub-supplier must be very good; first of all the agreements between the sub-supplier and supplier need to be better documented and complied. There has to be benefit in these agreements for both the integrator and the sub-supplier. Seen from the perspective of the sub-suppliers it would be beneficial for them if they are assured that they can deliver their parts to the integrator for a long time, by means of a long-term contract. It is important not to base this cooperation on price only but more so on quality of the supplied parts, service, terms & conditions and the division of risks on the long term.

In the new framework these sub-suppliers are added above the integrator; as a means to show that these sub-suppliers also influence the input for warranty costs. Since there are often many sub-suppliers (in the IST situation there are 69 for the Beaver dredgers) they are also represented as multiple sub-suppliers in the framework. For sake of simplification there are three sub-suppliers visualized, for the right interpretation it is good to realize that the number of sub-suppliers can vary depending on the number of parts that are needed for the integration of the capital good. The product reliability of a part is directly related to the product reliability of the final product; the integrator does not have any influence on this product reliability of the parts. The integrator, who is ultimately responsible for the final product and the extended warranty towards the client, manages the warranty policies. Of course only one ‘total’ warranty policy will be communicated to the client by the integrator. Claims made by clients will first be judged by the integrator, and if applicable communicated through to the responsible sub-supplier (or maybe even to different sub-suppliers). Even if the sub-supplier should handle the responsibility of the claim, the integrator will always be in the lead and keep communicating with the client. In the end any possible dissatisfaction of the client will damage the reputation of the integrator and ultimately the relationship between the client and the integrator.

Figure 18: Backward cooperation to achieve forward cooperation
8.1.3 - Warranty policies to control the warranty costs

For the development of extended warranty the warranty policies are not yet fixed (but variable). The policies determine what is included in the warranty and with which requirements. The warranty costs are dependent on the reliability of the product and the product usage. The better these variables are known, the better the expected warranty costs for the integrator can be estimated.

When the warranty costs of all parts and components are known, the warranty policy can determine what is included and excluded from the warranty, this will of course then again influence the total warranty costs and the risk for the integrator. As soon as the warranty policy is determined (from variable to fixed) the ‘covered warranty costs’ are known. Therefore the framework shows that the ‘covered warranty costs’ are determined when the warranty costs are checked by the warranty policy. These so called ‘covered warranty costs’ are an addition to the framework in the pre-launch stage.

![Figure 19: Warranty policies to control the warranty costs](image)

8.1.4 - Product usage influenced by Warranty policies

To be able to manage the product usage by the client (or actually operator of the client) there must be more control on the usage of the product. In the IST situation it is elaborately described what the different variables on product usage are. To steer the product usage the integrator should try to influence the product usage of the client in the best way possible. By prescribing the conditions of use for the client in the warranty policy the product usage can be better managed. For these conditions or requirements an example could be; guidelines on what maintenance needs to be done when. Another requirement that the integrator might demand is that the client proves his operators have the right level of expertise to operate the dredgers, or otherwise the integrator could obligate the client to follow a training.

![Figure 20: Product usage influenced by Warranty policies](image)
8.1.5 The new framework to develop extended warranty

By integrating all the mentioned points above a new framework is created to successfully develop extended warranty (figure 21) The key additions are:

1. The supplier is considered an integrator;
2. Cooperation with the sub-suppliers (backwards cooperation) is included in the framework;
3. The warranty policies control the warranty costs by in- or excluding parts, non- or renewing warranty and a possible decrease in the coverage of warranty costs for the integrator over time;
4. The product usage is influenced by the warranty policy so that the usage risks are (more) controlled by the integrator.

The warranty costs are completely dependent of the product performance, which in turn is determined by the product reliability and the product usage. To make a reliable estimation of the covered warranty costs it is of great importance that both the product reliability and the product usage are known. The first step for the integrator is to make sure that the product reliability and the product usage are determined in order to estimate the warranty costs, the warranty policies (also the policies in the backward cooperation) and ultimately decide on the covered warranty costs.

Figure 21: The framework to develop extended warranty
8.2 Modeling the extended warranty costs based on the framework

The framework developed in the previous chapter is structured to define the warranty costs that are influenced by several variables. In this paragraph the framework will be used as bases to built-up a model that is able to give an estimation of the warranty costs based on the same variables as the framework. The input for the model is based on the data from the case study at Royal IHC for the IHC Beaver 50. Since the input data is limited, many assumptions are made and the model is an approach of reality.

The goal of modeling of the framework is to make a realistic estimation of the warranty costs for the supplier of dredging equipment. The model of the framework provides insight in the impact of the variables on the warranty costs. The modelling of the influence of the variables on the warranty costs can help to focus when IHC is interested in generating more data in the future. The examined variables are:

1. The usage of the client;
2. The percentage of the component purchase price as part of the repair- & replacement costs;
3. The warranty period;
4. The in- or excluding of groups or systems.

These variables are adjustable on the front sheet of the excel model as shown in figure 22.

---

**INPUT**

<table>
<thead>
<tr>
<th>Sale price:</th>
<th>€ 2.750.000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warranty period:</td>
<td>start</td>
</tr>
<tr>
<td>In- or exclude groups/systems:</td>
<td>Complex systems</td>
</tr>
<tr>
<td>Repair &amp; replacement costs:</td>
<td>Superintendent Technical Services</td>
</tr>
<tr>
<td></td>
<td>Travel time to destination</td>
</tr>
<tr>
<td>Client properties:</td>
<td>Usage quality (α)</td>
</tr>
</tbody>
</table>

**OUTPUT**

<table>
<thead>
<tr>
<th>Decreasing failure rate:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing failure rate:</td>
</tr>
<tr>
<td>% of sale price:</td>
</tr>
</tbody>
</table>

---

8.2.1 Method for modeling the expected warranty costs

To approach the expected warranty costs with the influences of the variables, first a basic model has to be developed. The basics of the model for the warranty costs can be expressed in the *chance* and *effect*, the *chance* represents ‘the probability to failure’ and the *effect* represents ‘the expected repair or replace costs’. Multiplying ‘the probability to failure’ with ‘the expected repair or replace costs’ and add all systems and components together will give ‘the expected covered warranty costs’.
In figure 23 is displayed how the modelling and the developed framework are related. The red blocks are the input for the model and the green blocks are the variables that influences the expected ‘covered warranty costs’. In this chapter the basics and the variables of the model will be explained with the help of the developed framework.

![Diagram of the framework and modeling relations](image)

**Product performance**

As described in the previous chapter the Product reliability (B) and the Product usage (C) together form the product performance. These two variables are described below. The Warranty policy is a variable that is adjusted according to the influence of the product performance and therefore will be mentioned in a later part of the chapter.

**8.2.2 The probability to failure (B - Product reliability)**

The warranty costs are approached by the probability (chance) that a system or a component fails. In this model all systems and components have the same probability density function. Because the warranty costs are defined at system level, the bathtub curve is used (figure 24).

The probability to failure in the model is defined with the use the Expected Life Time (ELT) and the Mean Time To Failur (MTTF). Since this information is unknown, the data used is an estimation based on experience from the engineers at Royal IHC. The ELT and the MTTF are used as an input for the probability density function. The engineers at Royal IHC gave an indication on the complexity of the interaction of the systems; this is influencing the repair and diagnostic time and will be discussed later.

**The bathtub curve**

The bathtub curve is widely used for reliability engineering and describes a particular form of a hazard function in the shape of a bathtub: steep sides and a ‘flat’ bottom. The bathtub can be divided in three phases: the decreasing-, constant- and increasing- failure rate, as shown in figure 24 (Klutke, Kiessler, & Wortman, 2003). In the current model only the decreasing- and increasing failure rate are used as probability function to failure, the two applied functions are elaborated below and graphically shown in appendix F.
While most reliability references mention the bathtub curve, there is a considerable disagreement on its applicability. Some describe the bathtub as a “typical hazard rate” or that “only 10% to 15% of its applications follows the function” (Klutke et al., 2003). Considering, the bathtub curve is useful on a system level but not every system or product follows a bathtub curve.

**Usage of the client (variable 1) (C - Product usage)**

The product usage is included in the model as a variable and influences the warranty costs. In paragraph 5.5.6 product usage is described with the help of several usage scenarios by Murthy (2006). From these scenarios two factors are extracted; (a) the level of usage & (b) the level of usage intensity which are ad to the model.

**Usage quality (a)**

The level of usage quality is influenced by the components: operating skills and maintenance actions of the staff of the client. In the both failure rates is in the probability density functions the factor $\alpha$ is added. The factor $\alpha$ influences only the MTTF and the ELT. The factor has three levels; good, average and bad. The factor is currently set on an influence of plus or minus 10% for the good & bad level and for average set on zero.

**Usage intensity (b)**

The level of usage intensity is influenced by the components: usage intensity and the operating environment of the dredger. In both failure rates is the total probability density functions is influenced by the factor $\beta$. The model is only related to the total warranty period and not related to operation time of the dredger. The usage intensity influences the total probability density functions to add the effect of more or less intense usage of the dredger by the client.

**The probability density functions**

The application of the probability density function of the bathtub is a combination of two functions; (i) a decreasing probability density function and (ii) an increasing probability density function. This corresponds to the probability of failure of components by manufacturing defects (early failures) and the probability of failure of components due to wear and tear (wear-out failures).

For a more detailed and accuracy application of the framework should the probability density function of the failure rate be examined for every system, part or component, separately.

(i) **The decreasing probability density functions**

There are many theories developed over the years for decreasing failure rates. In the early 50’s D.J. Davis (1952) did an analysis of some failure data and proposed a failure rate for mechanical systems. The probability density function for a continuous exponential (Davis, 1952) has the form:

$$f(x; \lambda) = \lambda e^{-\lambda x}$$

where the factor $\lambda$ is influenced by the MTTF. This results in this equation:

$$f(x; \lambda) = \left(\frac{1}{MTTF}\right) e^{-x\left(\frac{1}{MTTF}\right)}$$
Adding the variable representing the usage of the client (variable 1)

By adding the client factors $\alpha$ and $\beta$ to the Probability density function results in the following equation that is applied in the modeling of the extended warranty costs:

$$f(x; \lambda; \beta) = \beta \left( \frac{1}{\text{MTTF} \cdot \alpha} \right) \cdot e^{-x \left( \frac{1}{\text{MTTF} \cdot \alpha} \right)}$$

$$f(x; \lambda; \beta) = \beta \left( \frac{1}{\alpha} \right) \cdot e^{-x \left( \frac{1}{\alpha} \right)}$$

The influence or the variable to the function can be found in appendix F.

(ii) The increasing probability density function

The increasing failure rate of the bathtub will be approached by cumulative distribution function (S-curve) of the normal distribution. A simplified approach of the S-curve of the cumulative distribution is a logistic function, a common applied function for the “S” shape. The logistic function finds applications in many statistics related fields, one is probability analysis. The equation of the logistic function is given by Davil Brandley (2007):

$$P(t) = \frac{M}{1 + Re^{-kt}}$$

$M = \text{maximum value}$

$R = \text{factor (influence location on the x axis)}$

$k = \text{growth rate}$

To apply this function right for the probability of failure following the factor $R$ becomes a fixed factor and the growth rate factor is dependent on the expected life time. The function is given in figure 5 for the same variables as in figure 4. The equation used is:

$$f(t) = \frac{100\%}{1 + 175e^{-\frac{11}{\text{ELT}}}}$$

$M = \text{maximum value} = 100\%$

$R = \text{factor (influence location on the x axis)} = 175$

$k = \text{growth rate} = \frac{11}{\text{ELT}}$
Figure 26: The logistic function used a s-curve for the increasing failure rate

When expected lifetime has passed the mode changes in a stepwise function. As a result, each time that the expected lifetime passes a part will be adding. This will result in the equation where:

\[ \gamma = \text{Expected Life Time (ELT)} \]
\[ t = \text{warranty period} \]

\[ f(t, \gamma) = \begin{cases} 
\text{for } t \leq \gamma: f(t; \gamma) = \frac{100\%}{1 + 175e^{-11/\gamma}}, & 0 \to t \\
\text{for } t > \gamma: f(t; \gamma) = \text{(stepwise function; integers)}, & t \to \infty 
\end{cases} \]

Example: If the expected lifetime is 12 months and the total warranty time is 24 months; in total two parts are required.

Figure 27: The combination of the logistic function and the integers function
Adding the variable representing the usage of the client (variable 1)
By adding the client factors $\alpha$ and $\beta$ to the Probability density function results in the following equation that is applied in the modeling of the extended warranty costs:

Probability density function including client factors $\alpha$ and $\beta$:

$$f(t; \gamma; \alpha; \beta) = \begin{cases} f \text{ for } t \leq \gamma: f(t; \gamma; \alpha; \beta) = \beta \left( \frac{100\%}{1 + 175e^{-\frac{11}{\gamma}t}} \right), \quad 0 \to t \\ t > \gamma: f(t; \gamma) = (\text{stepwise function; integers}), t \to \infty \end{cases}$$

The influence or the variable to the function can be found in appendix F.

8.2.3 The expected repair and replace costs (D - Warranty costs)
Due to the limited information available is an estimation to the expected repair and replacement costs required. The repair and replace costs are composed of (1) repair and diagnostic time, (2) the material costs, (3) the travelling time and (4) the hourly wage of an engineer. The composition of the costs is shown in table 22.

<table>
<thead>
<tr>
<th>Activity:</th>
<th>Costs:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Repair &amp; diagnose time</td>
<td>Depended on the complexity of the component/repair (categorized as easy/medium/complex)</td>
</tr>
<tr>
<td>2. Material costs *</td>
<td>% of the purchase price of the complete system/component</td>
</tr>
<tr>
<td>3. Traveling time *</td>
<td>24h</td>
</tr>
<tr>
<td>4. Hourly wage engineer *</td>
<td>€ 100,-</td>
</tr>
</tbody>
</table>

* Adjustable at front sheet.

Table 22: establishment of the repair & replacement costs

The repair and replacement (1) costs are determined with and estimation on the complexity of the systems. As shown in table 22, there are three levels easy, medium and hard. These levels are based on interviews with experienced IHC engineers. The levels influence the diagnose- & repair time.

The material costs (2) of a system are based on the calculation excluding the man-hours (labour), so the price for a single system is only a summation of the new material costs.

The traveling time (3) and the hourly wage of a superintendent (4) can be entered as independent variables on the front sheet of the model to chance them easily (figure 22).

<table>
<thead>
<tr>
<th>Activity</th>
<th>Diagnose</th>
<th>Repair</th>
<th>Factor / Day(s)</th>
<th>Travel</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy</td>
<td>6</td>
<td>6</td>
<td>0,5</td>
<td>24</td>
<td>36,00 hours</td>
</tr>
<tr>
<td>Medium</td>
<td>12</td>
<td>12</td>
<td>1</td>
<td>24</td>
<td>48,00 hours</td>
</tr>
<tr>
<td>Hard</td>
<td>24</td>
<td>24</td>
<td>2</td>
<td>24</td>
<td>72,00 hours</td>
</tr>
</tbody>
</table>

Table 23: Complexity index for the repair & replace costs

Variable percentage of the component purchase price (variable 2)
Since it is unknown what the average costs are for the repair of a system, are in the model for the IHC Beaver 50 the costs adjustable by vary the percentage of the purchase price. In case of a repair the material costs will not be the total purchase price of a complete system. The percentage can be adjusted on the front sheet as shown in figure 22.
8.2.4 The expected ‘covered warranty costs’ (A - Warranty policy)
In the end the warranty policies determine what is covered by the extended warranty and for which period. In this model for the IHC Beaver contains almost 70 systems, the systems are divided in groups and all groups can be in or excluded from the warranty. The warranty period is adjustable from six up to 60 months.

The warranty period (variable 3)
One of the most evident variables of modeling extended warranty is the variation of the warranty period. The warranty period determines over which period the warranty for the IHC Beaver 50 is given. The warranty can be adjusted on the front sheet of the model.

The in- or excluding of groups or systems (variable 4)
In the model the different systems can be switched on and off as a group or individually, to determine the influence of the systems on the warranty costs. The systems are classified into seven groups with cohesive characteristics.

1. Complex systems;
2. Engine;
3. Mechanical parts;
4. Moving steel structure;
5. Piping;
6. Stationary steel structure;
7. Wearing parts.

By in- or excluding the systems is IHC able to control the warranty costs for the system groups with a life time that is (i) to short related to the warranty period or (ii) unpredictable because of the sensitive influences of the product usage.

By selecting the groups that are included or excluded the total ‘covered warranty costs’ are determined.

8.2.5 Validation & verification of the model
In the first step a conceptual model was created to be able to obtain a feasible estimation of the problem entity, which was in this case the warranty behavior. After the obtainment of the conceptual model software program was chosen and a computerized model was created. This final computer model is able to make an estimation, using a given set of variables of the specific problem entity. An overview is shown in figure 28.

![Figure 28: Simplified version of the modeling process (Sargent, 2005)](image)

In order to determine whether the results of the model are “correct”, a validation and verification of the model are required, starting with a conceptual model validation to determine the feasibility of the conceptual model and its parameters. Due to insufficient data and lack of historical project information only ‘face
validation’ could be applied. Here, Three knowledgeable individuals working at Royal IHC confirmed the correctness of the behavior of the model. However, all of them recommended further research and data gathering in order to optimize the used parameters in the formulas and be able to use better validation techniques.

After the validation of the conceptual model, also the computerized model needs to be verified. Here, the implementation and correctness of the computer programming is checked (Sargent, 2005). At first, the main output is shown in a graph where the behavior of the problem entity was shown over time. Verifying the graphs with the expected behavior gave an idea of the correctness of the programming. Afterwards, extreme condition tests have been performed in order to check the correctness of the programming for various large variable values. Both verification methods obtained a positive outcome and the working principles of the computerized model are concerned to be “correct”.

Although the conceptual and computerized model is considered to be valid, further (operational) validation is recommended before further use of the model. Here, more data and project information should be gathered in order to apply better validation techniques.
8.2.6 Results & conclusion

The results of modelling of the framework are given in this paragraph together with the conclusion. The result is focused on showing the impact of the variables on the warranty costs. The warranty period variable will be shown in relation with all three other variables.

1) The impact of the percentage of the component price as a part of the repair- & replacement costs expressed in the warranty costs

To calibrate the modeling data to the case study, the warranty cost are determined without wearing parts. In the current warranty are the wearing parts also excluded. At the warranty time of 12 months, the comparison can be made to the case study where the warranty costs for 12 months are in average just over 1% of the selling price (IHC, 2014). Table 24 shows the results from the modeling of the extended warranty cost, at 12 months is a similarity with the results from the case study. The percentage of material costs for the repair- and replacement cost of 30%, this will be set as default percentage.

Further can be observed in figure 29 that the guarantee costs increase over time, this is because the probability to failure also increases. The slight wave movement lines can be explained by the interval of the MTTF and ELT. It can be seen that at 48 months the chance to failure increases, which is due to a large number of components with a MTTF or ELT of 48 months.

Table 24: Percentage of the component price as a part of the repair and replacement costs

<table>
<thead>
<tr>
<th>% of the component (new) price as a part of the repair- &amp; replacement costs:</th>
<th>10%</th>
<th>30%</th>
<th>40%</th>
<th>50%</th>
<th>70%</th>
<th>90%</th>
</tr>
</thead>
<tbody>
<tr>
<td>months:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0.42%</td>
<td>0.69%</td>
<td>0.83%</td>
<td>0.96%</td>
<td>1.23%</td>
<td>1.50%</td>
</tr>
<tr>
<td>12</td>
<td>0.60%</td>
<td>0.95%</td>
<td>1.12%</td>
<td>1.29%</td>
<td>1.63%</td>
<td>1.97%</td>
</tr>
<tr>
<td>18</td>
<td>0.87%</td>
<td>1.29%</td>
<td>1.50%</td>
<td>1.71%</td>
<td>2.13%</td>
<td>2.55%</td>
</tr>
<tr>
<td>24</td>
<td>1.32%</td>
<td>1.86%</td>
<td>2.13%</td>
<td>2.40%</td>
<td>2.94%</td>
<td>3.48%</td>
</tr>
<tr>
<td>30</td>
<td>1.92%</td>
<td>2.64%</td>
<td>2.99%</td>
<td>3.35%</td>
<td>4.06%</td>
<td>4.78%</td>
</tr>
<tr>
<td>36</td>
<td>2.59%</td>
<td>3.54%</td>
<td>4.01%</td>
<td>4.49%</td>
<td>5.44%</td>
<td>6.39%</td>
</tr>
<tr>
<td>42</td>
<td>3.31%</td>
<td>4.58%</td>
<td>5.22%</td>
<td>5.85%</td>
<td>7.13%</td>
<td>8.40%</td>
</tr>
<tr>
<td>48</td>
<td>4.17%</td>
<td>5.86%</td>
<td>6.71%</td>
<td>7.56%</td>
<td>9.25%</td>
<td>10.94%</td>
</tr>
<tr>
<td>54</td>
<td>5.17%</td>
<td>7.37%</td>
<td>8.48%</td>
<td>9.58%</td>
<td>11.78%</td>
<td>13.98%</td>
</tr>
<tr>
<td>60</td>
<td>6.24%</td>
<td>8.98%</td>
<td>10.63%</td>
<td>11.73%</td>
<td>14.48%</td>
<td>17.22%</td>
</tr>
</tbody>
</table>

Figure 29: percentage of the component price as a part of the repair and replacement costs (based on table (22)
2) The impact for the in- or excluding of parts & components on the costs for extended warranty

The difference between whether to include or exclude the wearing components is significant. The wearing components are causing great risks for IHC while the customer is managing this risk. The difference between the exclusion of wearing components & the engine or the excluding only the wearing components is smaller. This can be explained by the longevity of the engine is longer than 5 years and it is unlikely that the entire engine must be replaced.

In addition, a comparison with bringing the costs of the extended warranty under at the supplier (Pon Power), it shows that the reservation for warranty costs at the supplier for a 5 years warranty is smoothly rising in comparison the outcome of the model. As the provider has extensive knowledge and experience with the engine (CAT3512), are in the last column of the table the warranty costs determined by the model and the expense of the supplier add together to generate a realistic price.

Because of the knowledge & experience of the product and the dealer network that Caterpillar has over the world, it is advisable, when offering extended warranty, to forward the engine warranty to the expert of this product, the Caterpillar supplier.

<table>
<thead>
<tr>
<th>Warranty specified to systemgroups:</th>
<th>ex. Wear &amp; Engine</th>
<th>ex. Wear</th>
<th>incl. all parts</th>
<th>only the engine</th>
<th>Warranty costs engine by Pon Power</th>
<th>Difference</th>
<th>ex. Wear &amp; Engine + CAT warranty</th>
</tr>
</thead>
<tbody>
<tr>
<td>months:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0.66%</td>
<td>0.69%</td>
<td>0.87%</td>
<td>0.06%</td>
<td>0.00%</td>
<td>0.06%</td>
<td>0.89%</td>
</tr>
<tr>
<td>12</td>
<td>0.89%</td>
<td>0.95%</td>
<td>1.53%</td>
<td>0.17%</td>
<td>0.29%</td>
<td>-0.12%</td>
<td>1.98%</td>
</tr>
<tr>
<td>18</td>
<td>1.19%</td>
<td>1.29%</td>
<td>2.44%</td>
<td>0.44%</td>
<td>0.53%</td>
<td>-0.09%</td>
<td>3.68%</td>
</tr>
<tr>
<td>24</td>
<td>1.69%</td>
<td>1.86%</td>
<td>3.74%</td>
<td>1.02%</td>
<td>0.75%</td>
<td>0.27%</td>
<td>5.98%</td>
</tr>
<tr>
<td>30</td>
<td>2.36%</td>
<td>2.64%</td>
<td>5.27%</td>
<td>4.08%</td>
<td>4.58%</td>
<td>7.92%</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>3.15%</td>
<td>3.54%</td>
<td>6.65%</td>
<td>5.23%</td>
<td>5.86%</td>
<td>9.75%</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>4.08%</td>
<td>4.58%</td>
<td>7.92%</td>
<td>6.60%</td>
<td>7.37%</td>
<td>11.28%</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>5.23%</td>
<td>5.86%</td>
<td>9.75%</td>
<td>60</td>
<td>8.98%</td>
<td>12.91%</td>
<td></td>
</tr>
<tr>
<td>54</td>
<td>6.60%</td>
<td>7.37%</td>
<td>11.28%</td>
<td>8.05%</td>
<td>8.98%</td>
<td>12.91%</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>8.05%</td>
<td>8.98%</td>
<td>12.91%</td>
<td>1.86%</td>
<td>0.96%</td>
<td>0.90%</td>
<td>9.01%</td>
</tr>
</tbody>
</table>

Table 25: Impact of in- excluding parts & components on the extended warranty costs and data for the extended warranty costs of the engine from the supplier.

Figure 30: Impact of in- excluding parts & components shown in a chart (based on table 23)
3) The impact of product usage of the client on the costs for extended warranty.

The factors $\alpha$ and $\beta$ include the influence of the usage quality and the usage intensity of the client to the model. These two factors increase or reduce warranty costs according to the following statements:

- High intensive usage; assumes the entire risk of failure increases and the warranty costs become higher;
- Low intensive usage; assumes the entire risk of failure decreases and the warranty costs become lower;
- Bad usage quality; the MTTF and/or ELT becomes shorter, making the components fails sooner and the warranty costs will increase;
- Good usage quality; the MTTF and/or ETL become longer, making the components less likely to fail and the warranty costs will decrease.

In the chart in figure 31 are the four extreme usage factors compared to the average extended warranty cost (purple dot-line). The factors have a positive or negative influence of 10% (arbitrarily chosen) on the failure probability, it percentage can be adjusted in the model. The waves in the two upper lines come through the distribution of MTTF and ELT, which is enhanced by the factor $\alpha$, which has a direct influence on the MTTF, and ELT.

At high intensive usage and improper usage are the highest warranty costs and when less intensive usage and good usage the lowest warranty cost. It can therefore be concluded that the factors having the desired effect.

The size of the impact factor on warranty costs should be verified in the future with the actual usage order to achieve a better estimation.

Table 26: impact of the product usage factors of four extreme combinations and the average combination

<table>
<thead>
<tr>
<th>Usage quality:</th>
<th>a: Bad</th>
<th>a: Good</th>
<th>a: Average</th>
<th>a: Bad</th>
<th>a: Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usage intensity: β: Low</td>
<td>6 0.66%</td>
<td>0.59%</td>
<td>0.69%</td>
<td>0.81%</td>
<td>0.72%</td>
</tr>
<tr>
<td></td>
<td>12 0.94%</td>
<td>0.78%</td>
<td>0.95%</td>
<td>1.15%</td>
<td>0.95%</td>
</tr>
<tr>
<td></td>
<td>18 1.35%</td>
<td>1.02%</td>
<td>1.29%</td>
<td>1.65%</td>
<td>1.25%</td>
</tr>
<tr>
<td></td>
<td>24 2.01%</td>
<td>1.42%</td>
<td>1.86%</td>
<td>2.46%</td>
<td>1.74%</td>
</tr>
<tr>
<td></td>
<td>30 2.86%</td>
<td>2.00%</td>
<td>2.64%</td>
<td>3.50%</td>
<td>2.44%</td>
</tr>
<tr>
<td></td>
<td>36 3.84%</td>
<td>2.69%</td>
<td>3.54%</td>
<td>4.70%</td>
<td>3.28%</td>
</tr>
<tr>
<td></td>
<td>42 5.05%</td>
<td>3.46%</td>
<td>4.58%</td>
<td>6.18%</td>
<td>4.23%</td>
</tr>
<tr>
<td></td>
<td>48 6.56%</td>
<td>4.37%</td>
<td>5.86%</td>
<td>7.96%</td>
<td>5.34%</td>
</tr>
<tr>
<td></td>
<td>54 8.28%</td>
<td>5.49%</td>
<td>7.37%</td>
<td>9.82%</td>
<td>6.65%</td>
</tr>
<tr>
<td></td>
<td>60 9.78%</td>
<td>6.75%</td>
<td>8.98%</td>
<td>11.65%</td>
<td>8.18%</td>
</tr>
</tbody>
</table>

Figure 31: the impact of the product usage factors shown in a graph related to the extended warranty costs (based on table 24)
8.2.5 Conclusion on modeling the extended warranty costs

The framework can be used as an example to structure a model to the extended warranty costs and the impact of the variables. The impact of the variables and factors has the anticipated results. Royal IHC is able to use this model if IHC wants to offer warranty or extended warranty to give a more founded estimation of the costs.

However, the results of the modeling approach for the warranty costs of the IHC Beaver 50 were limited because of a shortage of reliable data. When the data is more precise, the model will become a model of reality. With the use of the model IHC is able to gather the data based on the input for the model. Nevertheless, the following basic points are required to give a more detailed estimation of the extended warranty costs of an IHC Beaver 50 from the viewpoint of the manufacturer (IHC):

1. Modelling at component level (instead of system level);
2. More reliability data of all components;
3. Failure rate per specific component;
4. Repair and replacement costs at component level;
5. Investigate the impact of product usage on the extended warranty costs or reliability;
6. Consider which services towards the client will improve the reliability.

A final recommendation for the usage of the model is to transfer the model from time related (one-dimensional), to operation hours related modeling and determine the average operating hours a year to define a two-dimensional warranty policy. This will reduce the risk for the manufacturer to offer the extended warranty.
8.3 Roadmap

All the information gained during the research including the interviews with employees of IHC, gave a basis to develop a roadmap for IHC. The roadmap or implementation plan gives the steps that have to be taken by IHC to offer extended warranty for the IHC Beaver series.

The steps are set out in figure 32 and structured in chronological order to give the best way of implementing. The first two steps can be executed simultaneously in order to win time. The last three steps are related to each other, but some sub-step can be done beforehand.

Time is not mentioned in the roadmap since time is dependent on many organizational aspects like the size of the team, the experience of the team, the expected result, etc. In the last step the development of a marketing and proposition plan is mentioned; these two plans are not in the scope of the research but are important to offer the extended warranty successfully to the market.

Figure 32 on the next page represents the roadmap to offer extended warranty and a large version can be found in appendix G.
Figure 32: The road-map to offer extended warranty
8.4 Validation

8.4.1 Why validation?
The framework and the (excel) model are designed with the knowledge and experience of a small group of people within a single case study. Due to limited available data several assumptions had to be made and the opinions of stakeholders had to be consulted to build up these models. These assumptions and the subjective opinions can limit the final outcome and applicability of the framework and the (excel) model. Therefore the framework and the (excel) model need to be validated in order to get an objective view, so that the validation results can be processed in the framework or in the (excel) model.

The framework and the (excel) model are based on the properties of a supplier of dredging equipment, in specific a supplier of cutter suction dredgers. The single case study is carried out based on experience and data of Royal IHC. The validation will elaborate if the results out of this research can be generalized, so that other dredging suppliers (or even other industries) are also able to apply the framework and the (excel) model for their equipment to achieve extended warranty.

The validation of the framework and the (excel) model will indicate the limitations and possible improvements for this research. This will help to improve the framework and (excel) model in the future. The (excel) model, which is derived from the framework, is a first step to a theoretical approach of the extended warranty costs by modelling product reliability. Developing such a model is a continuous process, which implies that improvements can be made continuously. To be able to use the (excel) model as an ‘active’ document a solid starting model is needed, therefore the validation is important to make improvements possible.

In the following paragraphs the method for the validation of the model and the framework is elaborated. In the end of the chapter the results and the implications for the model and the framework are presented. The next step is to update the model and the framework according to the validation results.

8.4.2 How to validate?
The framework, the (excel) model and the applicability of the research have the intended domain of the entire dredging industry, and they all need to be validated or verified. How to approach this validation process is executed with the help of the theory of Robert G. Sargent (2005).

Information and results out of modeling and frameworks will affect decisions based on these models. Therefore, it is important to carry out verification and validation according to Sargent (2005). Model verification is “ensuring that the computer program of the computerized model and implementation are correct” (Sargent, 2005). Model validation is “substantiation that a computerized model within its domain of applicability possesses a satisfactory range of the accuracy consistent with the intended application of the model” (Sargent, 2005). For this research the framework and the applicability of the research had to be validated and the (excel) model needs to be verified. Validation is a process where the result will be improved every time. It is difficult reach the perfect result but as long as the accuracy is satisfying the validation is sufficient.

Sargent (2005) recommends to apply the simplified model to verification and validation. The results of transferring the aspects of this research into the simplified model are shown in figure 34. In the orange top-boxes are the key elements of the simplified model (Sargent, 2005) in combination with the application of this research. Underneath the key elements is what should be done for the validation or verification.
8.4.3 Validation and verification

1. Conceptual model validation

1.1 Internal validation with an expert within IHC who was not involved in the development process of the framework to validate the framework internally. Question who has to be answered are:

- Are the theories, assumptions and characteristics right for the purpose of the framework within IHC?
- Does the framework “reasonably” represent where it is intention?

This is implemented by presenting the framework in an interview to Mark Notermans, technical manager at Royal IHC Services. The entire interview can be found in Appendix E2 and the key findings are described here.

In the validation interview with Mark Notermans a conclusion was that in the description of the characteristics an addition should be made; it is a standard product with default options. And ‘producing mechanical equipment’ should be changed in ‘equipment functional for hydraulic transport’.

The framework is a well-structured theoretical approach of the warranty costs, with the aim of forward cooperation, two more practical additions are suggested by Mark Notermans: (i) the importance of the soft-side relation with the client and (ii) the back to back coverage of the warranty policies towards the sub-supplier. The additions suggested by Mark Notermans are based on his expertise of the maritime industry he gained in his career. With the suggested additions to the framework, it is right for the use within Royal IHC.
1.2 External validation with an expert outside IHC in the same industry, to have an objective opinion about the framework and the possible application. Questions to be answered are:

- Are the theories, assumptions and characteristics of the framework also applicable for this business?
- What are the differences or conflict for this business?

The external validation is executed by discussing the framework with Rogier Vollenbrock, director and owner of a small shipyard in Oudenwater, where small size cutter suction dredgers are designed and built. The complete interview can be found in the appendix E2 and the key findings are described here.

In the validation interview with Rogier Vollenbrock the following conclusions are made: The research clarifies the influence of the client on de warranty cost in a clear matter and that it is important to find a method to control the influences of the client. This could be helpful to structure all the information that is needed to set up a new service like extended warranty.

The framework clearly identifies the relationship between the customer, the manufacturer and the product, this is also applicable to small CSD, and therefore useful for the company of Rogier Vollenbrock. The company is making smaller CSD’s and has its focus on a different market and business operations. Rogier concludes there is no need to develop a service for extended warranty because of the smaller scale of the company. When this will be the case in the future, the framework is a good starting point to determine the extended warranty costs.

The question central in the conceptual model validation was: Is the framework model structured in the right way? With the help of validation interviews the following conclusions can be made:

1) To the description of the characteristics some additions should be made;
2) The framework is well structured and ready for the use within IHC, with an addition of some practical suggestions;
3) Externally the framework is suited for the use in other organizations, such as the company of Rogier Vollenbrock. The framework is clearly identifies the relationship with different actors. This could be helpful for other companies that are willing to set up a new service like extended warranty.

2. Model validation
For validation of the model, separate validation steps are used. A detailed description is given in chapter 8.2.5.

3. Operational validation (for external validity)
Yin (2014) describes this as eternal validity where the explanation is to prove that the domain to which the research findings belong can be generalized. This strokes with the application given by Sargent (2005) and questions who has to be answered are:

- Does the outcome of the research cover the intended purpose of the research?
- Can the outcome be applied on other dredging equipment? And at other dredging suppliers?
- Can the outcome be applied on suppliers of equipment in general?

The purpose of the research was to find a way for a supplier of dredging equipment to apply forward cooperation. In the literature study several ways to achieve forward cooperation are defined and the choice for extended warranty is made based on the characteristics of the supplier of dredging equipment. The framework and the model show what is needed to offer the extended warranty and therefore forward cooperation.

The characteristics that are used for the model and the framework form the base for the outcome of this research. And with these characteristics the model and the framework give an answer to the main question.

The model and framework are designed for the niche market of the maritime industry, cutter suction dredgers. A next step is determining if the model and the framework are also applicable on other dredging equipment. By comparing the characteristics of the CSD and other dredging equipment a clear overlap is shown. Most of the other dredging equipment is also self propelled and certified.

When the model and the framework are used for another type of dredging equipment the base characteristics need to be adjusted accordingly. This also applies for the market changes or for the availability of data. The
first step when changing the characteristics is to check if extended warranty is still the way to go, or another option for forward cooperation needs to be chosen. By determining the current characteristics as input for the model, the model can be used for several dredging products within IHC. When the model is used for another product within IHC the changes and used data need to be checked thoroughly. When this is not done properly the risks of wrong interpretation of the results arrives.

The research is executed with the help of the case study within Royal IHC, but the question is whether the results are also applicable on other suppliers of dredging equipment. The model and the framework are based on the characteristics of Royal IHC and the IHC Beaver 50. The characteristics of Royal IHC and the IHC Beaver 50 can be compared with the characteristics of other dredging equipment suppliers and their products. The characteristics will probably have a significant overlap with the result that this framework and the model can be applied on other companies and products. The same warning is provided here: When applied on other dredging companies or dredging products, check thoroughly to prevent mistakes and miscalculations. Another important step is to check if the organization and product are suited for the extension of the warranty, In the case of Rogier Vollenbrock the conclusion was drawn that the market and the company are not suited for the extension of warranty.

The final question is if the results from this research are also applicable in other sectors. Dredging equipment has some specific characteristics like: usage all over the world, usage to excavate and transport soil over water and a small amount of dredgers available. With these specific characteristics the framework and model are designed and the research is executed. The framework and the model are also applicable on products that have similar characteristics. For most of the products the availability of the product is much higher, which results in a lower financial risk for the supplier. This will also influence the warranty costs.

The model and the framework are rather generic as long as the characteristics of the product and the company are applied and checked thoroughly.
9. Conclusion & Recommendations

9.1 Conclusion

9.1.1 General conclusion
The current situation in the shipbuilding industry, where prices are under pressure and where competition increases, asks for changes and the exploration of new markets to keep a strong position in the market. For a supplier of dredging equipment, the next step in the product life cycle is towards the operations & maintenance phases.
A benefit for the supplier of dredging equipment is that involvement in these phases will generate more knowledge about the use phase of the equipment. However, the supplier must be aware that he will not compete with his own clients. Forward cooperation combines these properties and is used more often.
The current warranty period is the only structural commitment that the supplier has with the client after the transfer of the dredging equipment. To realize forward cooperation it is shown that the current warranty period of one year is a good basis to extend towards a five-year warranty.

Based on the simplified characterization model of Murthy (2006) is the current warranty period analysed. This model has three variables and one dependent; the warranty costs are dependent of the variables (i) warranty policy, (ii) product reliability, (iii) product usage. Analysing the current warranty period led to the following conclusions:

Warranty policies
There are two important stakeholders for a supplier of dredging equipment: the clients; the future user and the sub-suppliers; who are responsible for more than 60% of the parts of a dredger. For both stakeholder groups terms and conditions are drafted with the purpose of sale of products and the procurement of parts. For the sale of products it is noticed that the difference between the ‘standard IHC terms’ and the ‘IHC contract’ is significant.
Warranty claims can be handled by IHC in four different manners; (i) reject, (ii) hand over to sub-supplier, (iii) hand over to insurance or (iv) accept and finance the claim. The claim procedure works sufficiently to solve the claim for the client. However, the warranty claims contain more information than is used at the moment therefore the feedback loop into the organisation has to be improved.

Product reliability
Amongst clients the dredgers from IHC have a reputation of being expensive though very reliable; the reliability of the product has widespread support. Also the engineers have a lot of experience on the design of these Beavers and have built up their experiences over years, IHC certainly has a lot of expertise in this area. However, data on the product reliability is missing at this moment. When aiming on forward cooperation it would be advisable to get better registration of the warranty claims and gain more data on the product reliability.

Product usage
The product usage is determined by the usage of the client and can be divided in the usage mode, the usage intensity, the operating environment, the operator skills and the maintenance. The product usage is estimated or approached by creating two user profiles; with low, average and high impact on the product performance. How the operators are using the IHC Beaver varies between the different clients and is little known within IHC, especially what the effect is of the usage on the warranty or reliability of the product.

Warranty costs
Warranty costs are estimated at 0.6% of sales price, however the warranty costs analysis of the past five years show that the warranty costs turned out to be 1.09% of the sales price. This shows that there is a big gap in how the warranty costs are currently estimated and how they turn out to be in practice. This also confirms that in the current situation is room for improvement to control the warranty costs. When the warranty period will be extended the impact will increase as well, therefor the main causes of the overrun of the budget need to be analysed.

The difference between the current situation (IST) and the perfect situation [SOLL] is that there are too many unknown variables involved. For the current situation these variables are partly manageable because the
The main research question is: “How can a supplier of dredging equipment achieve forward cooperation in the product life cycle?”

With the basis of the GAP analysis a direction for answering the research question is given. The conclusion of the GAP analysis provides an assignment for the research that sets out the structure for the answer of the research question: Develop a structure (framework) where the variables ‘product reliability’ and ‘product usage’ determine the warranty costs and where the ‘warranty policy’ is the last variable to define the definitive ‘warranty costs’. Thereby does the ‘warranty policies’ influence the ‘product usage’.

The analysis of the IST, SOLL and the GAP is structured with the simplified model of Murthy (2006) This simplified model is meant to analyse products in the post-launch stage. The simplified model of Murthy is used as a basis for the framework for the dredging equipment supplier to achieve forward cooperation in the pre-launch stage. The transformations from the model of Murthy into the new framework to achieve forward cooperation are listed step by step.

1. The supplier is considered an integrator;
2. Cooperation with the sub-suppliers (backwards cooperation) is included in the framework;
3. The warranty policies control the warranty costs by in- or excluding parts, non- or renewing warranty and a possible decrease in the coverage of warranty costs for the integrator over time;
4. The product usage is influenced by the warranty policy so that the usage risks are (more) controlled by the integrator.

![Diagram of the developed framework](image)

Figure 34: the developed framework

The warranty costs are completely dependent of the product performance, which in turn is determined by the product reliability and the product usage. To make a reliable estimation of the covered warranty costs it is of great importance that both the product reliability and the product usage are known. The first step for the
integrator is to make sure that the product reliability and the product usage are determined in order to estimate the warranty costs, the warranty policies (also the policies in the backward cooperation) and ultimately decide on the covered warranty costs.

Limitations of the research
This research is conducted on the IHC Beaver series where the available data is limited. The achieved benchmark study is conducted on smaller, less expensive and less complicated product than the IHC Beaver series what influences the SOLL situation. The research is conducted for a standard build dredger designed and build within IHC, to apply the research on custom build dredgers is more research required, one of the reasons is that the custom build dredger have different characteristics. An other limitation is the timeframe of the master thesis, this results in the fact that only one product of IHC is researched in the IST situation. To gain a complete overview of the IST situation within IHC more products should be analysed. To be able to give a solid answer to the main question to achieve forward cooperation, the research should be conducted at a similar product company. Since the research was executed within a commercial company a single case study had to be performed. A multiple case study at multiple companies was not possible in this research because a conflict of interest would occur.

9.1.2 Personal conclusion
The extension of the current warranty seems to be a logical step to achieve forward cooperation in the life cycle. Considering the gained knowledge of this research about the current situation within IHC, offering extended warranty will be a complex operation. Offering extended warranty requires more knowledge about the current situation and the behaviour of the variables. Cause of the unknown effect of the variables and the risks, the complexity to offer extended warranty will increase. To offer extended warranty first the current warranty period of one-year needs to be controlled in a more sufficient way. On the short term other methods to achieve forward cooperation could be more sufficient. The focus of this research is on the technical aspects of extended warranty from the viewpoint of the supplier or manufacturer. Technically it is possible to offer forward cooperation when more knowledge in gained. Before starting with the gathering of data to be able to offer extended warranty a research should be conducted to gain information if there is interest from the client towards extended warranty consists. Looking to the supply chain of the dredging equipment can be concluded that there are many different sub-suppliers involved in the construction of the dredgers. Currently the main indicator at the purchase department is the price. With the intention to offer extended warranty but also for the current warranty period backwards cooperation with the sub-supplier can benefit both parties. For the internal organisation of IHC is it important that the whole team involved with the product is informed when these strategy changes are carried out. The current market situation and the reorganisation within IHC offer a good opportunity to improve the external appearance of the company and not only the internal organisation. Important aspects are the marketing and proposition towards the client, these commercial aspects need to improve. This was not conducted in this research but my personal opinion is that a good relation with the clients will have a positive effect to achieve forward cooperation.

Future perspective
Forward cooperation is based on the improvement of the relation of the client and the supplier. Currently is the supplier forced by the market conditions to explorer the option to offer more service to the dredging market. If the potential clients are open for cooperation IHC is a good and reliable partner with lots of experience in the design and building of dredging equipment. From the view point of the client is the interest from IHC in the maintenance phase also new. Which method of forward cooperation the best method is will be encountered in the coming years. Currently IHC is developing and producing more and more parts internally because the price of a product will be better, what is unfavourable for the sub-suppliers and not stimulates backward cooperation. Internal production results also more responsibilities for IHC, like the improvement of the product and the responsibility of the warranty period. The purchase price is just one indicator of the total life cycle costs of a product, other indicators like services and warranty policies are currently not considered in the procurement. On the longer term IHC will probably taking more responsibility during the operation phase of the equipment this could lead to a reconsideration of the intern production.
9.2 Recommendations
Besides the above conclusion on how a supplier of dredging equipment can achieve forward cooperation, more specific information is found on the company of the single case study; Royal IHC. Thanks to the learnings from the case study some specific recommendations towards IHC can be made here. Furthermore some learning points from this research can be of valuable input for further research.

9.2.1 Royal IHC
The goal of this research for IHC was to increase their knowledge about methods to achieve forward cooperation and the stakeholder and variables that influences the (extended) warranty. Before offering extended warranty it is advisable that the current warranty will be improved. To improve the current warranty period recommendations based on the IST situation are:

- Only 'one' detailed (specification of parts and requirements to client) warranty contract with a warranty period of 6 or 12 months that is known internal within IHC;
- Make clear long-term agreements with the sub-suppliers (on price, quality, warranty (period) & responsibilities);
- Take more advantages out of the information of the warranty claims and make the client used to the fact that he delivers all information, also irrelevant information for the particular claim;
- Shortage of data and knowledge about the reliability of the Beaver. If IHC want to predicts the reliability; research must be done to the reliability;
- Limited information is available about the product usage of the clients. To improve the quality of Beaver dredgers more information about the product usage must be known.
- Warranty costs are higher than estimated and costs are difficult to breakdown. Register the warranty costs more detailed. Reserve budget for new development costs in the warranty period and like mentioned before; make agreements with the sub-suppliers.

Implementation of extended warranty within IHC
For the implementation of the extended warranty the roadmap that is described in chapter 8.3 will be a good guide. The main steps are:

1. Determine the reliability of the IHC Beaver series;
2. Gain understanding of the usage of the IHC Beavers;
3. Define the total warranty costs;
4. Determine the warranty policies;
5. Define the cover warranty costs

9.2.2 Additional research
This research is focused on the achievement of forward cooperation for standard built products by applying extended warranty. When transforming the application towards custom build product the characteristic will change. The impact of the changing characteristics can be interesting for further research.

The application of extended warranty is possible for a wide range of products; a common application of extended warranty is on customer goods and the application on capital goods is limited. Based on this research more research can be done on the application of extended warranty on other capital goods. This research is limited by the shortage of data, when more data is available further research can be done in the impact of the variables on the reliability and the warranty costs.
Bibliography


