LAPPEENRANTA UNIVERSITY OF TECHNOLOGY
Industrial Management and Engineering

Miika Kontturi

EFFECTS OF LIFE CYCLE PROFITS ON THE PROFITABILITY OF INDUSTRIAL HEAVY DUTY CRANES

Master's Thesis

Examiners: Professor Timo Kärri
University Lecturer Tiina Sinkkonen

ABSTRACT

Author: Miika Kontturi	
Name: EFFECTS OF LIFE CYCLE PROFITS ON THE PROFITABILITY OF INDUSTRIAL HEAVY DUTY CRANES	
Faculty: Industrial Management and Engineering	
Year: 2015	**Place:** Hyvinkää
Master's Thesis. Lappeenranta University of Technology 73 pages, 49 figures, 20 tables and 2 appendices. Examiners: Professor Timo Kärri and university lecturer Tiina Sinkkonen	
Key words: life cycle profits, after-sales, maintenance after-sales, profitability, pricing	

The goal of the thesis was to investigate how much after-sales profits a crane sale generates over the life cycle of the crane and the effects of these after-sales profits on the overall profitability of the crane.

The thesis utilizes theories about life cycle costing from an equipment and service supplier's point of view. However, instead of costs, the thesis is focused on the life cycle after-sales profits from maintenance services and spare parts provided for the sold crane.

The case study approach was chosen and a total of five cranes from three different segments were investigated. An eight-step life cycle profit calculation model was developed in order to analyze the chosen cases' life cycle profits systematically.

The results of the investigation suggest that the life cycle after-sales profits are significant in value. In the case analyses they accounted for between 20% and 44% of the overall life cycle profits of the case cranes. The after-sales profits should be taken into account already in the pricing when offering a crane to a customer.

TIIVISTELMÄ

Tekijä: Miika Kontturi
Name: ELINKAARITUOTTOJEN VAIKUTUS RASKAIDEN TEOLLISUUSNOSTUREIDEN KANNATTAVUUTEEN
Koulutusohjelma: Tuotantotalous
Vuosi: 2015 **Paikka:** Hyvinkää
Diplomityö. Lappeenrannan teknillinen yliopisto. 73 sivua, 49 kuvaa, 20 taulukkoa ja 2 liitettä. Tarkastajat: Professori Timo Kärri ja yliopisto-opettaja Tiina Sinkkonen
Hakusanat: elinkaarilaskenta, elinkaarituotot, hinnoittelu, kannattavuus, kunnossapito
Tutkimuksen tavoitteena oli selvittää kuinka paljon erityyppiset nosturit tuottavat myyntikatetta jälkimyynnistä nosturivalmistajalle sekä jälkimyynnistä saatavan katteen vaikutusta myydyn nosturin kokonaiselinkaarikannattavuuteen. Työssä hyödynnetään elinjaksokustannuslaskennan teorioita laitteistovalmistajan ja palveluntarjoajan näkökulmasta. Keskiössä on kuitenkin kustannusten sijaan elinkaarituotot, joita nosturi valmistajalleen elinkaarensa aikana todennäköisesti tuottaa siihen myydyistä kunnossapitopalveluista ja varaosista. Työ toteutettiin case-tutkimuksena ja tutkittavia nostureita oli kolmesta eri segmentistä yhteensä viisi kappaletta. Case tapausten käsittelyä varten kehitettiin kahdeksanosainen laskentamalli, jonka avulla pyrittiin selvittämään systemaattisesti kaikkien nosturien elinkaaren aikaiset tuotot liittyen kunnossapitopalveluihin ja varaosamyynteihin. Tutkimuksen tuloksena todettiin, että elinkaaren aikana jälkimyynnin katetuottojen olevan varteenotettavia. Jälkimyynnin tuottojen osuus elinkaaren aikaisista katteista oli case tapauksissa 20% ja 44% välillä. Jälkimyynnin katetuotto tulisikin pyrkiä huomioimaan jo nostureita tarjottaessa.

PREFACE

This Master’s thesis has been written for Konecranes Finland Oy in Hyvinkää. The journey from an empty paper to a finished work has been extremely educational. I would like to thank my instructor Heikki Kajanto for providing a very interesting and timely topic for the thesis.

The topic was related to both equipment and service business areas, so there were a large number of people involved in various ways over the course of writing the thesis, a big thank-you to all of them. Especially I would like to thank the branch managers in Finland and the UK for help and support over the data collection and verification phase of the work.

I would also like to thank Professor Timo Kärri for providing feedback and guidance in the thesis’ contextual and structural matters.

Hyvinkää 12.5.2015

Miika Kontturi

Table of contents

1 INTRODUCTION

1.1 Background

The world is changing and ways of doing business are changing with it. Old ways of doing business are replaced by new ones that suit the current needs better. Nowadays in many industries the customer spending is directed more and more towards services, not in the actual products. For example, in 1999 in the US rail industry spending on new locomotives was 1.4 billion USD whereas the spending on maintaining and operating the locomotives and their infrastructure was 20 times more at 28 billion USD (Wise & Baumgartner 1999, p.134). The original equipment manufacturers (OEMs) should understand what kind of sales and profits are available from the later life cycle phases, after the product has been sold.

In general, competition in traditional equipment manufacturing is increasing. As the competition is increasing, available profits tend to decrease. After-sale service provision is a way to find new sources for revenue and profit. The service provision can also be a way to differentiate offers from competition. (Meier et al. 2010, p.1175)

This thesis is about gaining understanding of the overall business potential of a process crane equipment sale. These cranes are integrated into the customer's process and they are also critical for the process. This makes the reliability requirements high and provides good after-sales opportunities, such as maintenance service contracts.

The life cycle costs from the customer's point of view have been studied in a few previous theses at Konecranes (see Ylönen 2000; Gylling 2004; Karjalainen 2005), but life cycle profits from Konecranes' point of view have not been clearly identified for different types of process cranes. The current difficult situation in all manufacturing businesses in general, where the profitability of equipment sales is under pressure the life cycle profits, i.e. what future profits the equipment sales enable, has become more important for the management. The topic for the thesis was provided by the financial department of Industrial Crane Solutions business unit.

In Konecranes’ case the problem is not in that the service potential would not be recognized in general, but rather that it is not clear at the time of sale what kind of sales and profits can be generated by the sold equipment in the future, in comparison to a situation where the equipment is not sold. Considering these future sales early enough could possibly lead to different pricing/ sell – no sell decisions. The information about the life cycle profit can also be utilized to gain a better understanding about the relationship between service and equipment sales. In addition, it helps with decision making for the best of the whole company, instead of partial optimization. In order to be able to start paying more attention to the profits that an equipment sale generates in the future, a better understanding of life cycle profits is required.

For the overall profitability it might be crucial, who provides the maintenance for the crane, and whose components have been used in the crane as that determines what spare parts the crane will use. The life cycle profitability of the equipment depends on the answers to those two questions.

1.2 Konecranes – Lifting businesses

Konecranes is a large company that provides customers a wide variety of lifting equipment and services. The equipment business includes shipyard, light lifting and industrial cranes. In addition to these, lift trucks are also in Konecranes’ product portfolio.

Figure 1 presents a highly simplified organization model. In Konecranes the business is divided into two different business areas: equipment and services. The equipment area takes care of selling new equipment and it is the service business area’s responsibility to take care of the after-sales opportunities for the sold equipment. In this division into two different business areas, looking at the whole picture of combined equipment and service sales is not common on a crane level.

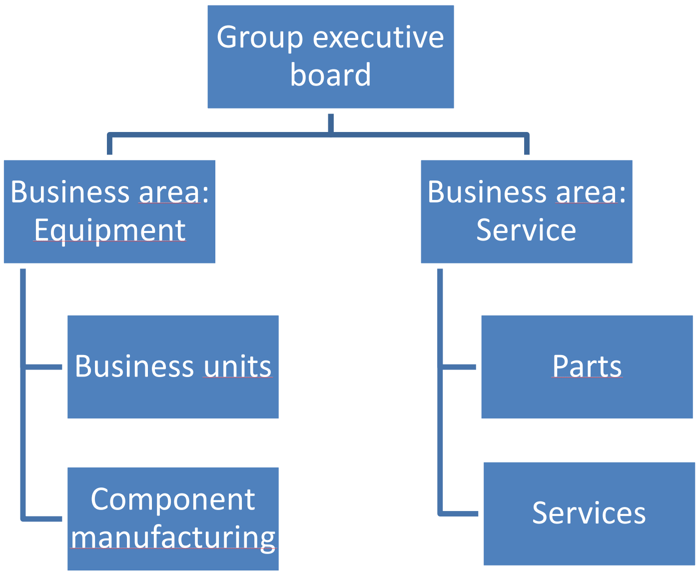


Figure 1: A simplified organization model. (Konecranes 2014, p.34)

Figure 2 presents the overall sales and EBIT (earnings before interest and tax) by business area. As shown by the figure 2 according to 2013 figures business area services accounted for less of the sales than the business area equipment, but for most of the EBIT.

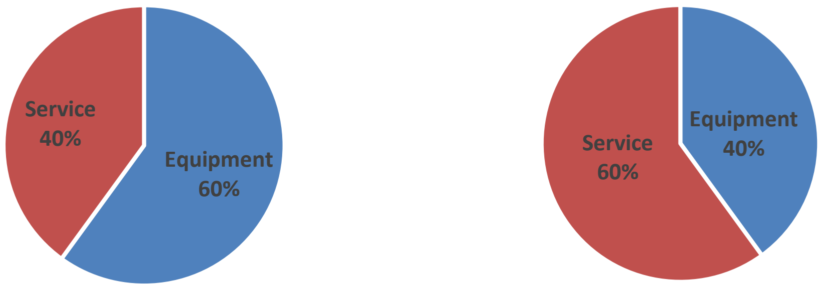


Figure 2: Sales by business area (left) and EBIT by business area (right). (Konecranes 2014, p. 2)

In this thesis, the focus is on Industrial Crane Solutions (ICS) business unit's industrial cranes. These cranes are designed for complex heavy duty tasks and they are many times a critical part of the customer's processes. Due to the criticality of the cranes, reliability is important. In general, these cranes need regular maintenance and changing of wear and tear components. Providing services for the customers to take care of these cranes brings customers added value. In this thesis, cranes for customers in petrochemical, steel and waste-to-energy segments are taken a look at.

1.3 Goals and delimitations

The purpose of the thesis is into provide an insight to what profits the equipment sale may generate in the future. The focus is on spare part sales and other service sales. Larger modernizations, which usually take place close to the end of the original life cycle, are not taken into consideration nor consultation services.

The ability of the chosen case cranes to generate profits over a longer period of time is analyzed based on their available history data. The word “profit” or “profitability” in the context of the work refers to the contribution margin, which is calculated by: sales – variable costs. No fixed costs have been considered in this thesis.

The work is based on three research questions:

1. How much after-sales profits do the chosen types of cranes generate?
2. How do these after-sales profits compare to the initial sales profits?
3. Could considering the after-sales profits have an effect on the possible sales price?

The main goal is to provide information about the combined equipment and service sale profits of different cranes for managerial decision making purposes, such as pricing decisions.

The research is delimited to Industrial Crane Solutions (ICS) business unit’s heavy duty cranes. There are 27 different segments with different types of cranes each, but only cases from three segments are considered: petrochemical, steel and waste-to-energy (WTE). More specifically, the case cranes are coker, charging and waste handling cranes.

1.4 Research methods

As the goal is to increase understanding and provide information about the current situation, the case study approach was considered suitable to achieve these goals (Saaranen-Kauppinen & Puusniekka, 2006). The case cranes for the study were searched from the segments of interest. A life cycle profit model with an eight-step procedure was then created to analyze these cranes. Literature and articles about life cycle costing (LCC) provided a basis for the life cycle profit model. Life cycle costing provides a good theoretical background on how the whole life cycle should be considered, and this also applies to profits.

The case cranes had to be from the segments of interest and, in addition, they needed to have Konecranes maintenance contract, to be 5 years or older and to have crane specific history data recorded and available. Finding suitable case cranes took time, and even with the chosen cases there was some data lacking. The best available cases were chosen. The case data for them were collected from multiple different systems.

Due to the data being from over a long period of time and from multiple systems, there are reliability concerns. These concerns were minimized by verifying the magnitude of the estimated sales from the area's branch manager by a questionnaire for steel and WTE cases. Used coker crane cases are located in India and Konecranes India provided the best available history data for these cranes, but no separate survey was made for these cranes.

1.5 Structure of the report

The thesis is divided into four different parts. They are depicted in figure 3. First, an introduction to the topic is presented providing an insight into the background of the work and the company itself. In the second part, the theoretical background is presented. In that part the concepts of life cycle costing, different kinds of analyses and maintenance theories are presented.

In the third part, a life cycle profit estimation model and case analyses are presented. This part first describes how the cases are analyzed step by step and then presents the actual case analysis results. Finally, in the last part the results are analyzed and conclusions are made.

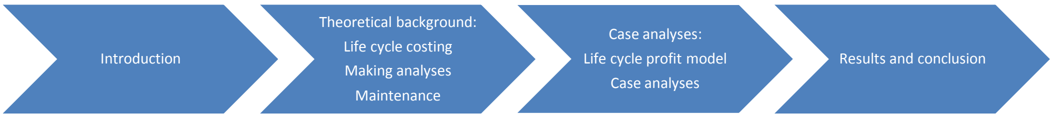


Figure 3: Structure of the report.

2 LIFE CYCLE COSTING AND PROFIT

2.1 General

A product's life cycle refers to the time interval in between a product’s conception and its disposal, whereas life cycle costs are the cumulative cost of a product over its life cycle (BS 1998, p.2). White and Ostwald (1976, p.39) define the life cycle cost as: “the sum of all funds expended in support of the item from its conception and fabrication through its operation to the end of its useful life.”

Life cycle costing (LCC) was first developed in the 1960’s as a procurement technique, but later it developed into being a tool for planning. The technique was developed in the US department of defense after it was noticed that the operating and maintenance costs were a big part of the budget. It was realized that it was important to take those costs into account already when procuring new equipment. (Uusi-Rauva & Paranko 1998, p. 48)

A product’s life cycle may be short or long, life cycle costing, in general, is more useful for products with a long life cycle, as the operating phase costs tend to be higher with longer life cycle. For cranes, for example, the life cycle may be over 20 years and for a computer only around 3 years. Life cycle costing (LCC) aims to take into consideration all significant costs, no matter what phase of life cycle they are formed in whether it the supplier or customer who pays for them (Taipale 1998, p. 16).

Even though typically the acquisition cost is only a small part of the total life cycle costs of the equipment, still many times it is given too much emphasis in decision making (Barringer & Weber, 1996, p.4). The acquisition costs can be described as the tip of an iceberg, whereas operating and maintenance costs are hidden under water. This is depicted in figure 4. By comparing the tips of icebergs it is difficult to say which one is the biggest, since the size of the underwater part is hidden. The same applies to costs, by looking at the acquisition cost alone it is difficult to say which option will have the lowest costs in the long run.

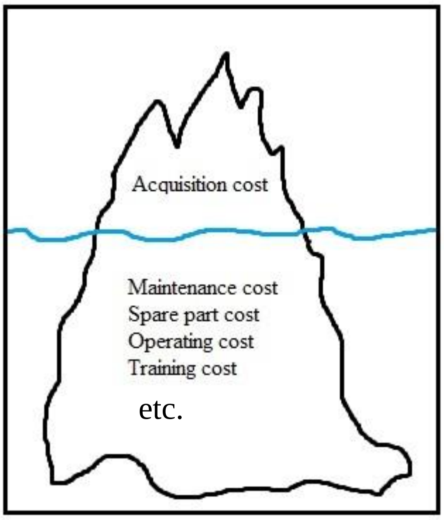


Figure 4: Hidden life cycle costs (Uusirauva & Paranko, 1998, p.50).

To be able to take into consideration all the costs over the whole life cycle requires extensive amount of data and understanding of the product in question. In the limitations of LCC listed by Barringer and Weber (1996, p.5-6) most of the limitations concern the accuracy of the estimations and data acquiring difficulties. The results from LCC are only estimates and the estimates cannot be more accurate than the inputs used for the estimates. Also a lot of data is required to make the estimates, and often only limited amount of data is available. Though, in many situations even a rough estimation is better than no estimation at all. According to White and Ostwald, (1976, p. 39) in its broadest form the life cycle cost analysis can be used to estimate all relevant costs for the decision making purposes.

Life cycle profit (LCP) and life cycle analysis (LCA) are variations of LCC. Life cycle profit takes into consideration profits the equipment generates in use in addition to the costs, life cycle analysis considers the environmental aspects during the life cycle.

2.2 Life cycle phases

2.2.1 Life cycle in life cycle costing (LCC)

A life cycle can be separated into phases. IEC categorizes life cycle into six different phases: 1. concept and definition, 2. design and development, 3. manufacturing, 4. installation, 5. operation and maintenance and 6. disposal (BS 1998 p. 3). These stages are also depicted in figure 5.

Figure 5: Life cycle phases (BS 1998, p. 3).

White and Ostwald (1976, p.39) divided a life cycle into three different sections that cause costs over the life cycle of the product. The sections are engineering and development, production and implementation, and operating. The accumulation of costs over these three sections for a product is depicted in figure 6.

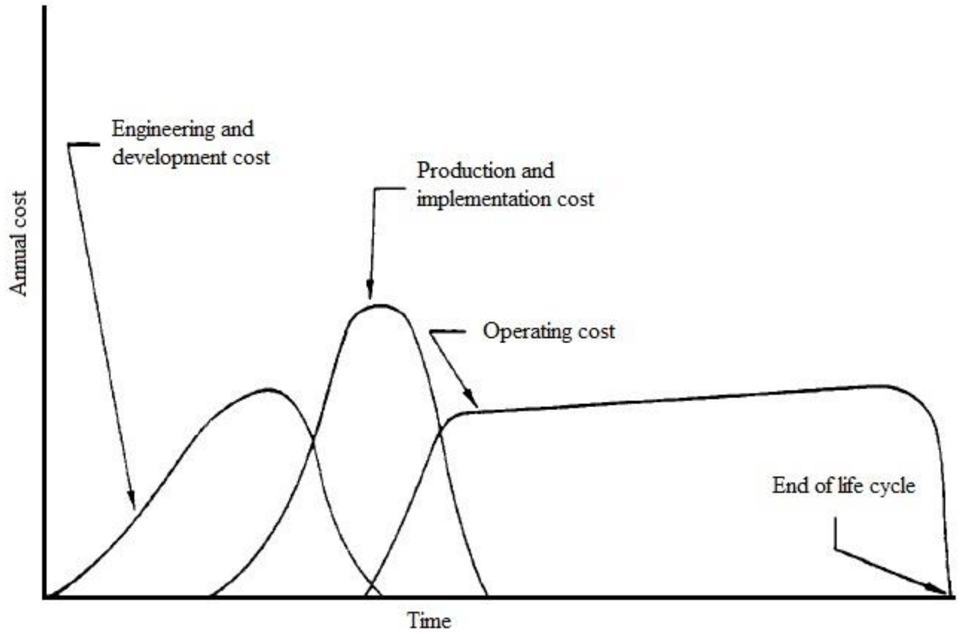


Figure 6: Stages of life cycle costs (White & Ostwald, 1976, p. 336).

2.2.2 Cost commitment over the life cycle

Most of the funds are committed in the first phases of the life cycle, i.e. a lot earlier than when the cash flow occurs. Figure 7 depicts the difference between the commitment of funds and the funds expended. It is estimated that over half of a product's life cycle costs are determined in the conceptual design phase by the choices made about the product's features, reliability and used technology (Fabrycky & Blanchard 1991, p. 12). According to Järvenpää et al. (2005, p. 131) approximately 80% of the life cycle costs are committed by the end of the design and development phase. From the customer's point of view this means that once equipment has been acquired, there is little possibilities to reduce the operating costs of the machines.

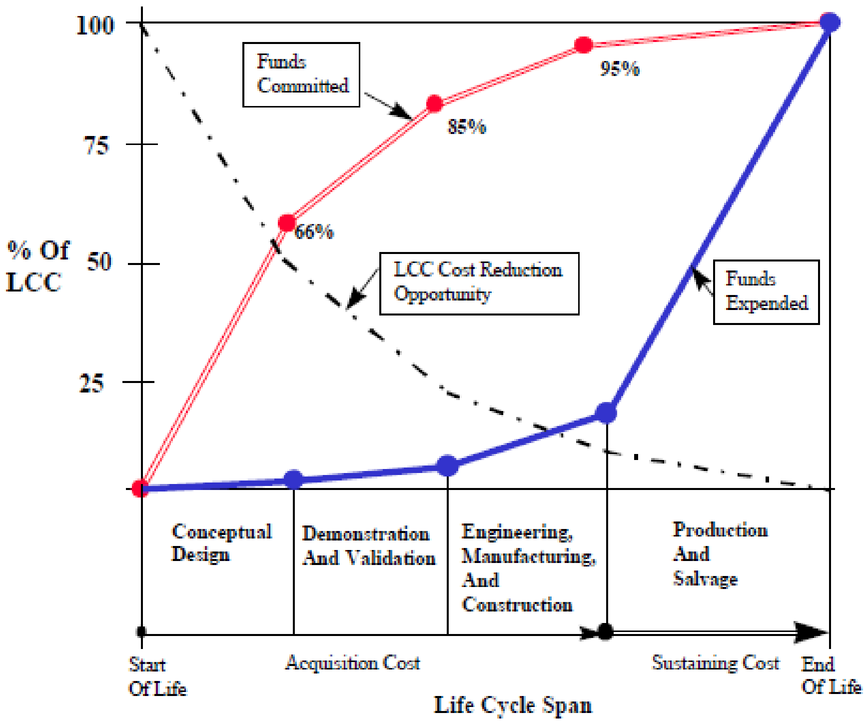


Figure 7: Committed funds vs. funds expended (Barringer & Weber 1996, p. 28)

The committed costs become reality in the operating phase of the life cycle. Opportunities for cost reduction also decrease significantly after the design and development phase, since it becomes difficult to make major changes to the product in the later phases. The cost of making changes increases after the design has been done. It has been estimated that making the same change costs 1€ in the concept phase, 10€ in the design phase, 100€ in the manufacturing phase and 1000€ in the operating phase (Hagbert et al. 1996, p.190). Therefore, the life cycle costs should be considered in the early phases of the product life cycle to have as much control over the costs as possible.

2.3 Life cycle costs and profit making opportunities

Life cycle costs can be divided into two different cost categories; the acquisition costs and the cost of ownership. This can be presented by the following formula:

$$LCC = Cost_{acquisition} + Cost_{ownership} \qquad (1)$$

The customer has to eventually pay for the costs from all of the life cycle phases, since the cost of acquisition includes the costs from the first phases of the life cycle and the profit for the supplier. The cost of ownership consists of the costs from the operation and maintenance and disposal.

The ownership costs can be further divided into more specific cost groups. One possible division is presented in figure 8. As the figure shows, the ownership costs can be divided into operating costs, scheduled maintenance, unscheduled maintenance and conversion/decommission costs. Different sources use different ways to divide the costs into more specific categories. For the purpose of this study along with the acquisition cost, the customer's ownership costs of spare parts and maintenance (planned and unplanned) are the most interesting. This is because these customer's costs include opportunity for sales and profit for the supplier. The cost of lost production can be large for customers with critical equipment (BS 1998, p.4), but as this thesis was done from the supplier's point of view these costs have not been considered.

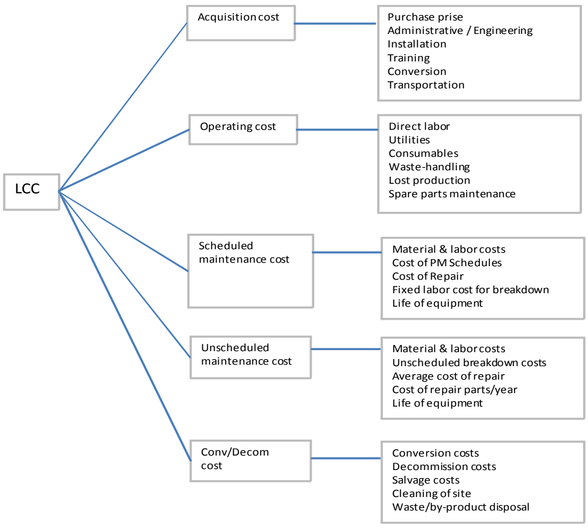


Figure 8: SAE model of LCC (Barringer & Weber 1996, p. 20)

Now, if we consider the supplier's profit making possibilities, there are at least two possible ways to make profit over the life cycle: 1. the equipment sale, and 2. providing services during the operating phase. By providing services to the operating phase the supplier can gain profits from the customer's operating costs. Figure 9 depicts these profit-making possibilities.

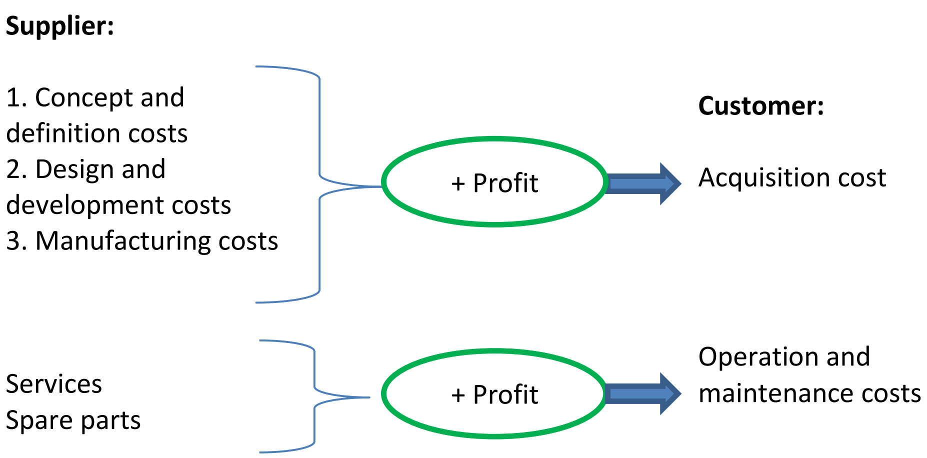


Figure 9: Supplier's profit-making possibilities.

One goal for this study is to provide an insight into the profit making capabilities from the operating phase. This requires data about what kind of after-sales services have been provided for the customers and what the profit-making capabilities of those services are.

Kaufman (Woodward, 1997, p. 337) has provided an eight-step approach for LCC formulation shown in appendix 1. This idea was used to construct the steps in figure 10. The main difference is in step 3, in which, instead of costs, profits are considered. As step 3 indicates, at the time of sale profits can be earned from the equipment sale itself and also from the initial parts sale. During the operating phase profits can be earned by providing services (e.g. consultation, maintenance etc.) and by selling spare parts. In the case of not selling a crane, the profits from equipment sale, initial spare part package sales and future spare parts sales will not occur. Maintenance services can still be offered to the customer even though the crane would have been sold by a competing company.

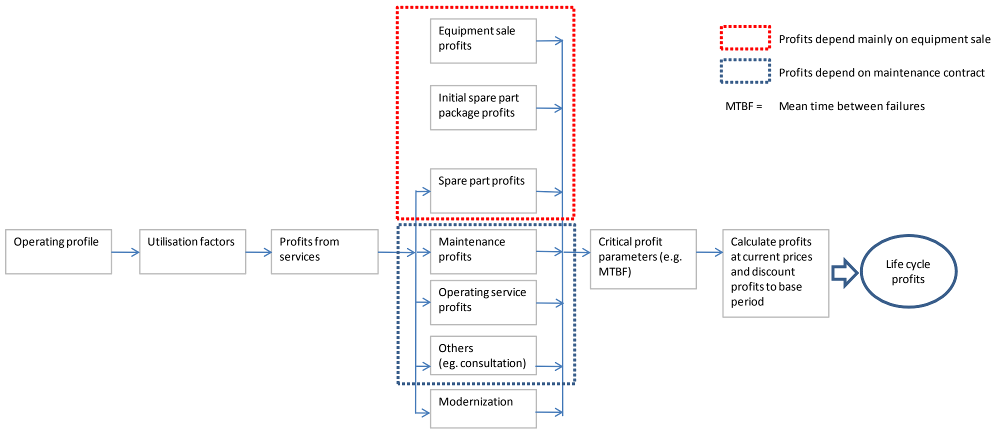


Figure 10: Life cycle profit opportunities for the supplier

The profits from the equipment sale are pretty well understood at the time of sale, but the possible future profits that the sale enables is not that well understood.

2.4 Use of LCC

Depending on the need, LCC can be applied to the whole life cycle or to a part of it. The period of life over which the analysis is performed should be tailored according to the needs of the situation (BS 1998, p.4).

The British standard lists eight common types of decisions where LCC is used to provide input. Those are:

1. Evaluation and comparison of alternative design approaches.
2. Assessment of economic viability of projects/products.
3. Identification of cost drivers and cost effective improvements
4. Evaluation and comparison of alternative strategies for product use, operation, test, inspection, maintenance, etc.
5. Evaluation and comparison of different approaches for replacement, rehabilitation/life extension or retirement of ageing facilities.
6. Allocation of available funds among the competing priorities for product development/improvement.
7. Assessment of product assurance criteria through verification tests and its trade-off.
8. Long-term financial planning. (BS 1998, p.2)

Barringer and Weber (1996, p.4) list six different uses for LCC. Korpi and Ala-Risku (2008, p.249) have done a literature review to analyze the usage of LCC based on Barringer and Weber's six categories. The categories and their usages are listed in table 1. The LCC method can be used by both the end user and the supplier of equipment, though both use the method for slightly different purposes.

Table 1: The use of LCC (Korpi & Ala-Risku, 2008, p.249).

Use	**No. of studies found by the review**	**Percentage [%]**
Affordability studies	6	11
Source selection studies	21	38
Design trade-offs	25	45
Repair level analysis	7	13
Warranty and repair	3	5
Supplier's sales strategies	1	2

As the table 1 shows, according to Korpi and Ala-Risku's (2008, p.249) study, design trade-offs and source selection studies are the most popular uses for LCC. As can be seen from the various different uses listed by different sources, LCC analysis can be used to provide input into variety of different decisions. Typically in life cycle costing the costs are of the main interest. In this thesis the main interest is on the sales and profits that a product sale may generate over its life cycle.

2.5 Life cycle costing process

Many sources propose different life cycle costing procedures (eg. BS 1998; Fabryck 1991). Kawauchi and Rausand (1999, p.10) have combined these into six basic steps found to be common in all of the proposed procedures. Figure 11 depicts these processes with sub activities to each process.

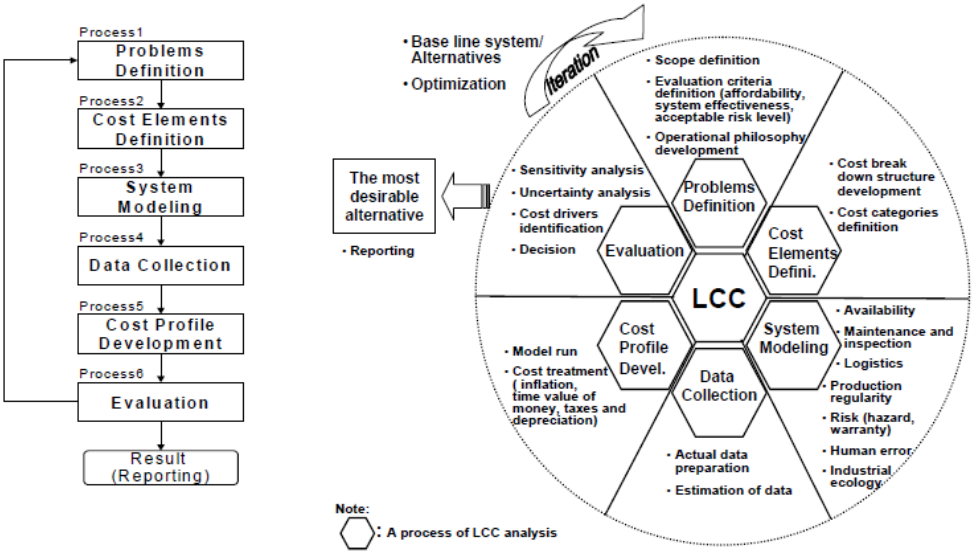


Figure 11: Six LCC processes and their sub activities (Kawauchi & Rausand 1999, p.10-11)

In the problems definition process the problems should be clarified and decisions about the scope have to be made i.e. which program phases are modeled, what equipment and activities are included etc. The scope defines what cost elements are considered in estimating the LCC analysis. Kawauchi and Rausand also suggest that the effectiveness and the way the equipment is operated should also be considered along with the costs. (Kawauchi & Rausand 1999, p.12)

In the second step the cost elements should be defined. This requires breaking the costs down into smaller pieces by finding different cost categories, and assigning them to different parts of the equipment in different phases of life cycle. For this, information is needed about their cost category, work breakdown and life cycle phase. (Kawauchi & Rausand 1999, p.13)

Modeling a system means finding relationships between the cost elements, defined in the previous step, and input parameters. Existing models for different cost elements can be used, if available. The system should be modeled from various different viewpoints, such as availability and maintainability. (Kawauchi & Rausand 1999, p.16)

The data collection step requires the identification of input data and a reliable data source. If it is possible to find data to quantify cost elements directly, this data can be used. For cost elements with non-available data, estimations can be made by using stochastic, parametric or analogous techniques. Data about the operation are sometimes difficult to find, since they are stored in the operating companies' in-house databases. (Kawauchi & Rausand 1999, p.30)

In the fifth step the cost profile should be constructed, that illustrates the costs vs. life cycle as shown on figure 12. The cost profile is important information, as it provides a summary of the costs related to the cost elements. (Kawauchi & Rausand 1999, p.32)

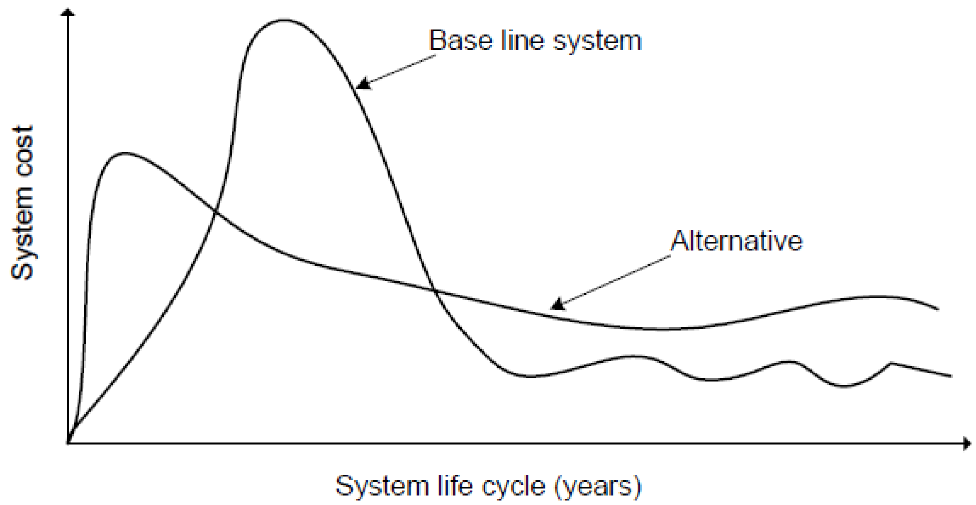


Figure 12: Example of a cost profile (Kawauchi & Rausand 1999, p.32)

In the final step the results are evaluated. One important part of this step is to make a sensitivity analysis to check how changes in the input variables affect the results. In a sensitivity analysis only one variable is changed while the others are kept constant, and this way it is possible to find the most critical variables in the calculations. (Kawauchi & Rausand 1999, p.34)

2.6 Time value of money

The time value of money has to be taken into account when considering cash flows from a long period of time. One Euro today is worth more than one Euro in the future. Also, the further in the future this future Euro should be received, the more uncertain the receipt is. Basically, the worth of benefits and costs is more the earlier they are received. This is the reason why the future cash flows need to be discounted into the present value. This can be done by using a discounting rate. (Burch 1994, p.1084)

2.6.1 Discount rate

Discounting is the process of transforming the future value of money into a value at a specific point of time (usually present), it is an inverted process from calculating the interest (Neilimo & Uusi-Rauva 2012, p. 216). The discount rate is the rate used in the process of calculating this value of future money. A real or nominal discount rate can be used depending on whether inflation is taken into account in the cash flows or not. When the cash flows are expressed in the real value (i.e. without inflation) then the real discount rate should be used, whereas when the cash flows include inflation, the nominal rate should be used. (Boussabaine 2004, p.37-38)

The relationship between the two types of discount rates is presented in the formula below (Neilimo & Uusi-Rauva 2012, p. 217):

$$i_r = \frac{i_n - s}{1 + s} \tag{2}$$

where, i_r= real discount rate

i_n= nominal discount rate

s = inflation

No matter which type of rate is used, choosing the correct value for the discount rate is a challenge. The chosen rate should project the future changes, but as always when projecting the future, there is a lot of uncertainty involved (Boussabaine 2004, p.37-38). The chosen rate largely affects the results, the higher the discount rate is the less the present value for future cash flows is going to be and vice versa.

Woodward (1997, p. 338) lists popular ways of determining the appropriate discount rate. The listed methodologies are:

- Using the current or expected rate the organization must pay for the use of its borrowed funds.
- Using the rate of return that could be expected from loaning money.
- Using the lowest rate of industrial borrowing for a reliable company.
- Using a riskless discount rate (treasury bond) adjusted with the expected inflation.

2.6.2 Net present value (NPV)

In the net present value (NPV) method all the future cash flows are discounted by a selected rate to the present. The NPV value gives a simple value to be compared between different options. The higher the NPV value is, the more benefits there are for the company. NPV should be above 0, otherwise the value is destroyed by the investment. The formula for calculating the NPV is presented below. (Neilimo & Uusi-Rauva 2012, p. 218)

$$NPV = \sum_{t=0}^{n} \frac{S_t}{(1+i)^t} \qquad (3)$$

where, S_t is the cash flow of year t

t is the time in years

n is the length of time period, in years

i is the discounting rate

In the calculations it is assumed that the cash flow takes place at the end of the year. This is a simplification, but a necessary one to make the calculations less laborious. (Neilimo & Uusi-Rauva 2012, p. 214)

2.7 Analyses

This subchapter presents sensitivity analysis and cost-volume-profit (CVP) analysis. The sensitivity analysis is an important part of LCC calculations. The CVP analysis is used in the thesis to explain the results on larger scale to the company.

2.7.1 Sensitivity analysis

When making estimations there is always uncertainty involved. With the sensitivity analysis it is possible to investigate how the calculations change if a variable changes assuming the other variables do not change, i.e. ceteris paribus. Each variable should be changed one by one and after every change in a variable the calculations are recalculated to investigate how the change affects the final outcome. This way it is possible to find out what are the most critical variables whose accuracy affect the end result the most. Most attention should be paid to these critical variables in order to make them as accurate as possible. (Neilimo & Uusi-Rauva 2012, p. 225)

2.7.2 Cost-Volume-Profit analysis

In the cost-volume-profit analysis the relationship between sales volume and profits is analyzed. This analysis takes into consideration both variable and fixed costs related to the products sold. (Horngren et al. 2006, p.67)

Figure 13 presents a profit-volume graph. In the figure the profit-volume line represents the profits or losses made depending on the units sold. If the units sold are less than the breakeven point, then loss is made and vice versa. For a multiproduct company this line can be created by using weighted average sales price and contribution margin-%. With the analysis it is possible to calculate how many units are required to be sold in order for the business to make profit, assuming that the fixed costs do not change. (Horngren et al. 2006, p. 72-75)

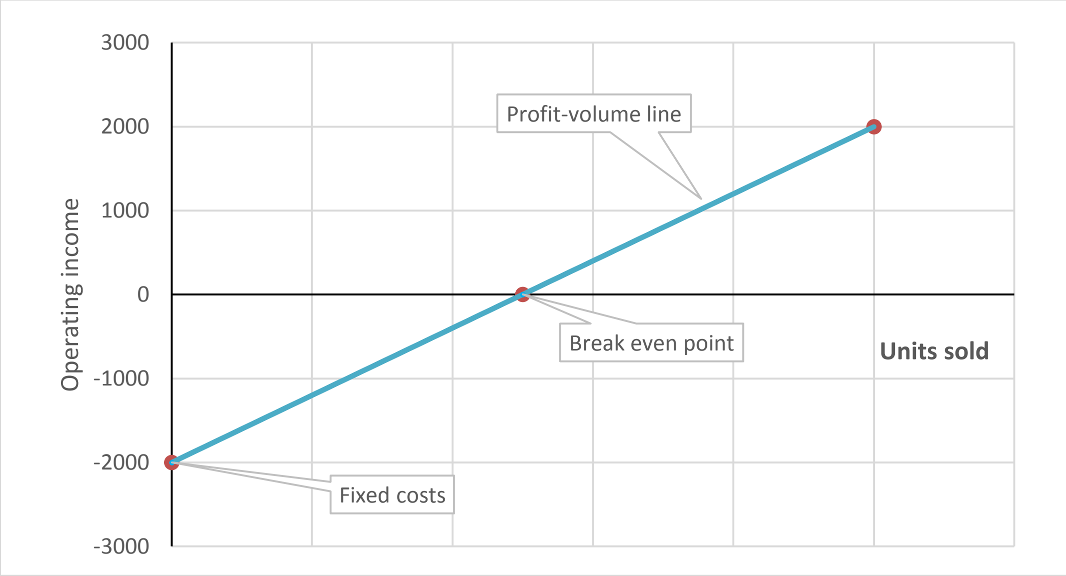


Figure 13: Profit-volume graph.

2.8 Probability of failure

Spare part and maintenance needs of a machine are largely driven by the number of failures. Therefore, when making estimations about the life cycle after-sales composed of spare part and maintenance service sales, it is important to have an understanding of how machines fail over their life cycle.

Failures of machines are traditionally assumed to be due to technical reasons, such as bad engineering or durability. However, according to Nakajima this is not the case and there are five main reasons for failures (Järviö et al. 2007, p. 61):

1. The machine is operated incorrectly.
2. Too narrow expertize of the operators and maintenance personnel. Potential failures are not noticed before actual failure happens.
3. Age related performance decrease is not noticed, fixed or it is accepted.
4. Usage conditions are not optimal. For example, dirt may cause performance issues and cause overheating.
5. The machine is not engineered for the actual usage or ambient conditions.

The number of failures can also be linked to time as presented in the bathtub curve in figure 14. In this bathtub curve it is assumed that there are more failures in the beginning of the life cycle as there is infant mortality, over time these decrease and the failure rate stays low over the machine's service life, but after some time there will be increasing number of wear out failures as the machine gets older. (Lappeenrannan teknillinen yliopisto 2013, p. 1)

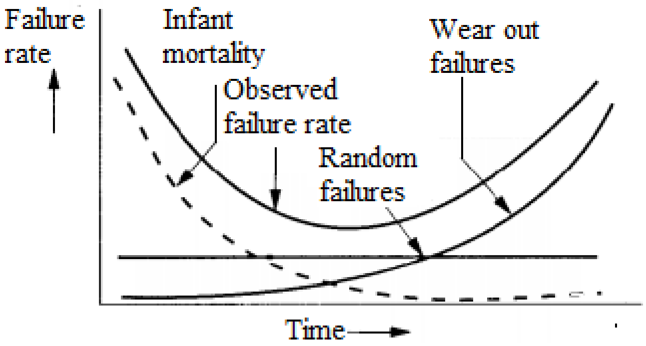


Figure 14: Bathtub curve. Different types of failures over the life cycle of a machine.

Nolan and Heap have found in their research that there are in fact six different types of failure patterns of which three are based on time and three are random. According to Moubray, in industrial usage failures tend to be more often random than time based. (Järviö et al. 2007, p. 59) The six patterns are presented in figure 15.

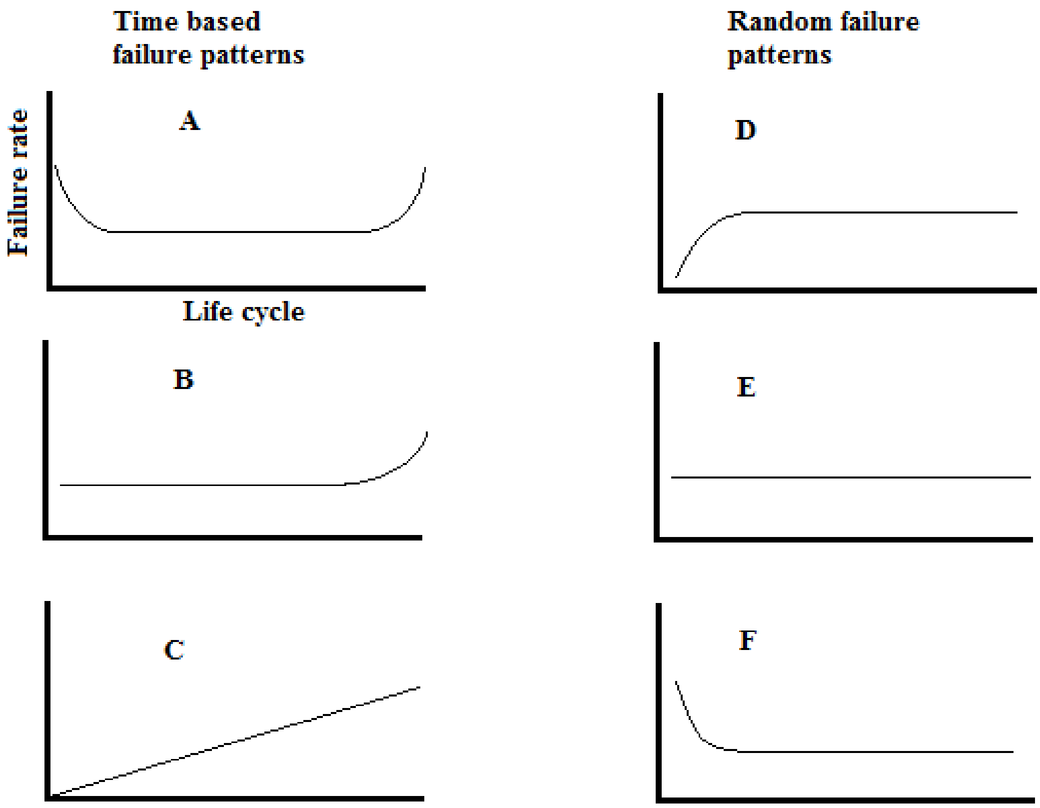


Figure 15: Six failure patterns. (Järviö et al. 2007, p. 58)

In the figure 15 patterns A, B and C are time based failure patterns. In pattern A there is a high infant mortality rate, then a more stable period before wear out failures. In pattern B there is no infant mortality, but after some time wear out failures occur. In C the failure rate is constantly growing over time. (Järviö et al. 2007, p. 57-58)

In figure 15 D, E and F are random failure patterns. In pattern D in the beginning there are little failures, but over time the failure rate rises to a constant level. In pattern E the failure rate is constant for the whole life cycle of the machine. And finally, in pattern F the failure rate is higher in the beginning of the life cycle and lowers to a constant rate after some time. (Järviö et al. 2007, p. 57-58) Table 2 lists results from different studies about the proportions of different types of failures in industrial machines.

Table 2: Different failure patterns and their proportions. (Järviö et al. 2007, p. 59).

	Type of machine	Civil aircrafts	Civil aircrafts	Ships	Submarines
	Research	UAL 1968	Broberg 1973	MSP 1982	Submepp 2001
Time based	A	4%	3%	3%	2%
	B	2%	1%	17%	10%
	C	5%	4%	3%	17%
Random	D	7%	11%	6%	9%
	E	14%	15%	42%	56%
	F	68%	66%	29%	6%

According to these researches, failures occur in industrial machines mainly due to random reasons. The current impression is that for the complex machines used today component specific failure patterns are lost in the mass and the failure rate tends towards pattern F. (Järviö et al. 2007, p. 60)

3 LIFE CYCLE PROFIT CALCULATION MODEL

3.1 General

There are a few possible sources for profits over the 20 year life cycle of a crane that are considered in this work. They are depicted in figure 16. Of after-sales the focus is on spare parts and maintenance services. Modernizations and consulting are not considered other than what has already been provided for the case cranes. The analysis is made from the equipment manufacturer's point of view.

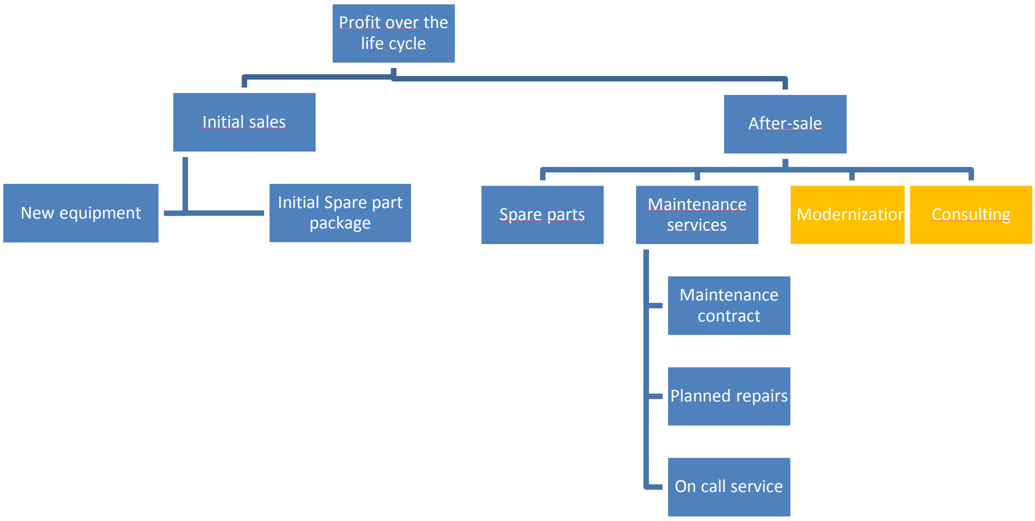


Figure 16: Profit making possibilities.

The goal is to find out all the profits from each of the sources for the case cranes over their actual life and, based on this data, estimate the overall profits over 20 year life cycle from the base year. The net present value technique (NPV) is used to get the estimated profit at the chosen base year (order year or installation year). Then it is possible to compare the profits from initial sales (new equipment + initial spare part package) to the after-sale profits.

Equipment sale and its profits are fairly well known at the time of sale. After-sale sales and profits are more difficult and need an analysis of the existing cases and analogous estimation, so that the life cycle profit can be taken into account.

The profit estimation of after-sales is done in 5 steps for the analysis part and in additional 3 steps for the estimation tool part of the thesis. The steps are presented in table 3. All the cases are addressed in these same steps, even though, as each case is different, there are some differences between cases how these steps are executed. Spare parts and maintenance services are addressed separately.

Table 3: Steps for after-sales profit estimation.

Analysis	1.	Find out actual €/a sales, estimate pipeline profits-% and calculate estimated profits for the sales.
	2.	Calculate real values of these profits, i.e. eliminate inflation.
	3.	Estimate the life cycle profits of remaining years also in real values.
	4.	Calculate the estimated life cycle NPV of after-sales profits.
	5.	Compare the estimated NPV of life cycle after-sales profits to the initial sales profits (new equipment + spare part package) and make a sensitivity analysis.
Estimation tool	6.	Find out/estimate the average working cycles per year of the case cranes and calculate the estimated working cycles over the life cycle.
	7.	Divide the NPV of spare part profits by the value from (6) to get spare part sales NPV €/working cycle. This value is used by the tool to estimate the spare part after-sales profit potential.
	8.	Divide the maintenance service life cycle NPV by the value from (6) to get a NPV €/working cycle value for maintenance service after-sales profits.

3.2 Analysis step 1

In the first step, sales related to a specific crane are collected from the data bases, maintenance personnel and other sources. To estimate the profits from sales an, average profit margin was determined.

3.2.1 Spare part analysis

Spare parts are usually sold during maintenance operations and they are therefore many times included in the strategic product (SP) of the maintenance operation. For example, if a spare part is needed in an on call job, the spare part sale is also included as an on call SP. In this thesis, all the spare parts have been separated and taken into account separately as spare parts and only labor is considered in the maintenance service SPs.

The spare part sales have been investigated from internal databases (e.g. Q3, Siebel). Since the data is gathered over a relatively long period of time, making sure the data is absolutely accurate is impossible. Also, there might be some years where the data was not available at all. The data accuracy has been checked as far as possible together with experts, but there are still possibilities for errors in the data.

The profit from spare parts is divided into frontline, part center and factory. This is depicted in figure 17 below.

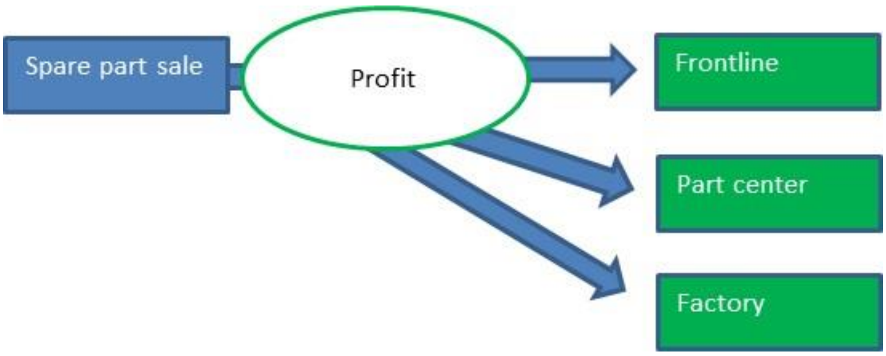


Figure 17: Profit from spare part sale.

The profit margins were estimated for frontline, part center and factory separately. To estimate the frontline margin in general the known end customer price and frontline cost were used to back up the estimate.

The profit to part center was estimated by using the whole of 2013 spare part sales to industrial heavy duty process cranes and taking an average of the profit margin.

There are differences in different spare part profit margins, but in general a wide variety of parts have been sold to the case cranes, so an average is assumed to provide a good enough accuracy. Similarly, the profit to factory was estimated by using the averages of complete factory sales to parts business in 2013.

3.2.2 Maintenance service analysis

Maintenance services are divided into three different categories. The first is maintenance contract, the second is planned repairs and the third is on call services.

Maintenance contracts include changing oil and typical checks of the equipment condition. Also, if the customer requires quick response time, this is included in the contract as well. Contracts are usually negotiated annually with the customers and the price is increased according to risen costs, so the real value of the contract stays approximately the same over the whole contract time. In the calculations an assumption is made that there is a contract over the whole life cycle of the crane.

Crane specific annual maintenance contract values were gathered from different area branch managers and other maintenance sales from databases (Siebel, Q3). Expert judgment was required for determining a single crane's proportion of the contract's value. Again, an average profit margin was used to estimate the profits.

3.2.3 Summary of analysis step 1

Because crane specific profit data was not available directly, many estimations needed to be made even when analyzing the past data. Table 4 summarizes what was estimated and how in the analysis of the actual sales data.

Table 4: Estimates used to determine the profits from case specific sales data.

	What is estimated	Used estimate
Spare parts	Frontline profit-%	Average, backed up by available case data.
	Part center sales price (% of the end customer price)	Expert judgment, backed up by available case data.
	Part center profit-%	Average of 2013 crane part center (CPC) profit-%.
	Factory sales & profit-%	Average of 2013 factory sales to part center.
Services	Service contract sales & profit-% (SP21)	Expert judgment, backed up by the overall contract data.
	Planned repairs profit -% (SP22R)	Expert judgment, backed up by overall data from databases.
	On call service profit -% (SP23)	Expert judgment, backed up by overall data from databases.
	Others (SP22M, SP27)	Expert judgment, backed up by overall data from databases.

3.3 Analysis step 2

In the second step the nominal values for profits from step 1 are converted into real values. This is done by using the producer price index (PPI) values as a measure of inflation in Finland and the UK, and wholesale price index (WPI) in India. This is because PPI is not yet measured in India (India times 2014). The same indexes were used for both spare parts and services.

This step is necessary for making the NPV calculations with single discount rate. The used inflation rates for different years in different countries are presented in figure 18.

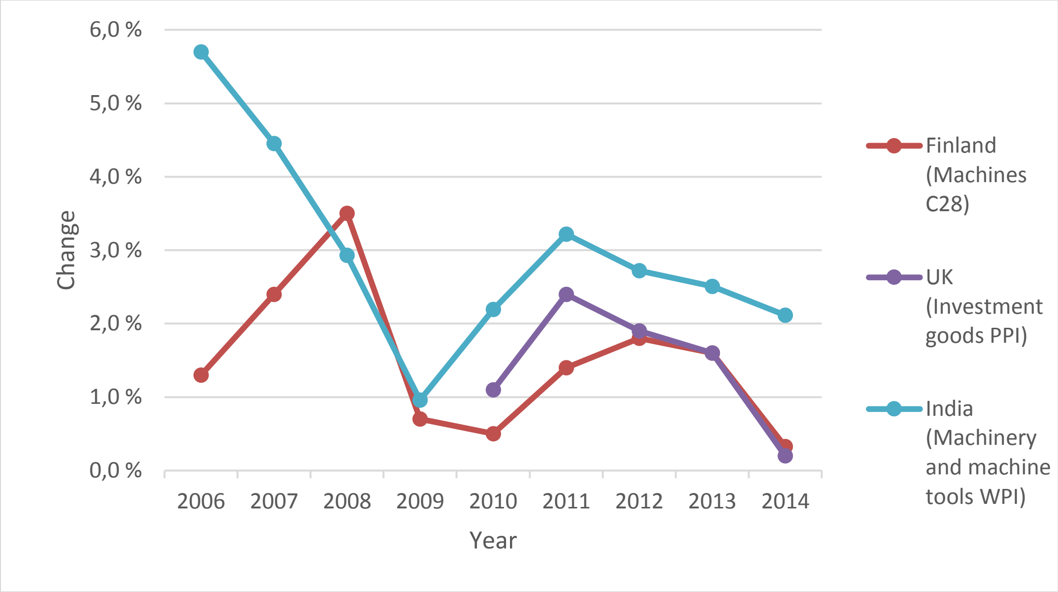


Figure 18: Inflation in different countries. (Tilastokeskus, 2014; OECD, 2014; Government of India, 2014)

3.4 Analysis step 3

In the third step the values from steps one and two are used to estimate the life cycle profits for a case crane. In addition to the values from the previous steps also knowledge of the bathtub theory is used to create the estimates.

Theories suggest that the failure rate of complex machines could be assumed to be constant (see chapter 2.8). The theories are talking about the number of failures, but in this work the value of these failures is considered, and one failure could be more expensive than the other. With the available data it could not be determined how exactly the annual profits to equipment manufacturer from a crane behave in a longer period of time. Therefore, the bathtub curve was used to avoid overestimation of the life cycle profits.

Based on the bathtub theory, an assumption was made that the spare part and maintenance needs are higher in the beginning years, lower over the middle period and again higher over the last years of the life cycle. The assumption decreases the chances for radically overestimating the future profits, though it increases the chances for underestimations as well. However, underestimation was seen as the lesser of the two evils. Figure 19 depicts the assumed accumulation of profit over the life cycle of a crane.

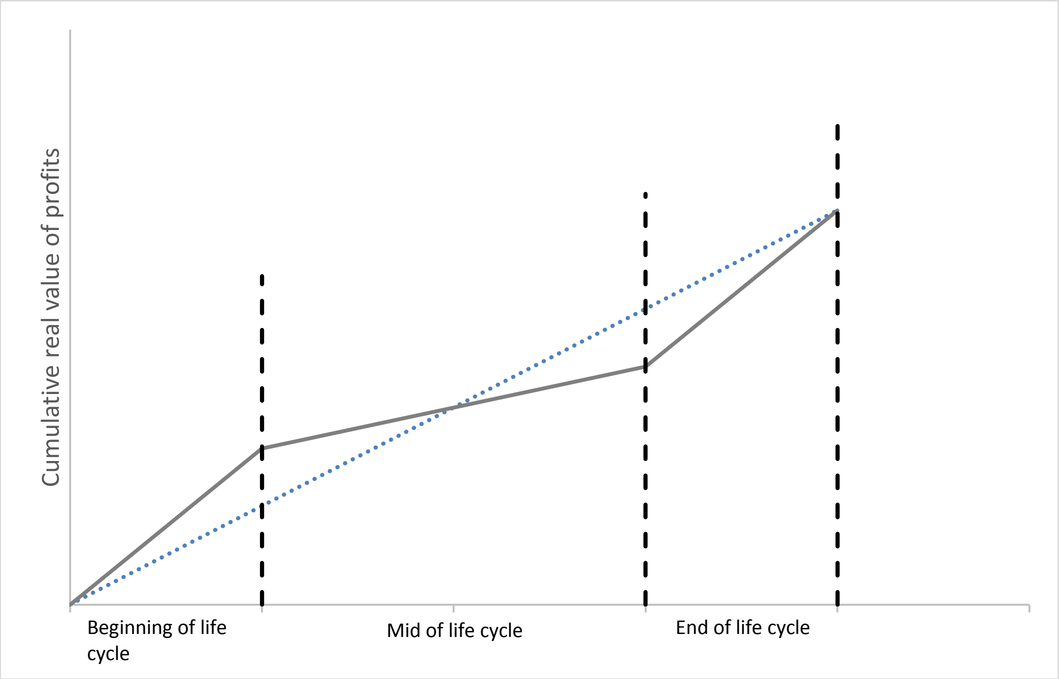


Figure 19: Accumulation of profit Euros over three different life cycle phases.

Due to this assumption there were two questions to be answered:

1. What is the time frame of the beginning and end of the life cycle?
2. How do the mid-cycle profits compare with those in beginning and in end of the life cycle?

To answer the first question, the time for which data was available was considered as the beginning of the life cycle. The middle period was considered to begin directly after the last year with data available (from 2015 onwards). This assumption was made no matter how many years of data was available in different cases. The end life cycle was set to be the last five years of the life cycle. Again, there was no real data to back up this use of 5 years as the time period for higher maintenance needs. The last years of the life cycle also have a relatively small impact on the net present value.

To reduce the possibility for overestimating the life cycle profits of the case cranes, the middle life cycle profits were calculated using formula 4. The average of actual profits were multiplied by a decreasing factor of 0,75 to get the estimated profit over the middle period.

$$P_{mid} = \frac{\sum \ Ep}{n} * d \qquad (4)$$

where,

P_{mid}= Middle life cycle profits

Ep= estimated profits of the available actual sales data over n years (in real values)

n = number of years with data.

d = decreasing factor

Case by case there were differences in calculating the middle life cycle profits depending on available case data. If some past years were missing data, they were excluded from calculating the Ep value, and also excluded from n. These years with zero data would have overly decreased the P_{mid} value. Over the end life cycle profits were estimated to equal the beginning life cycle's average profits.

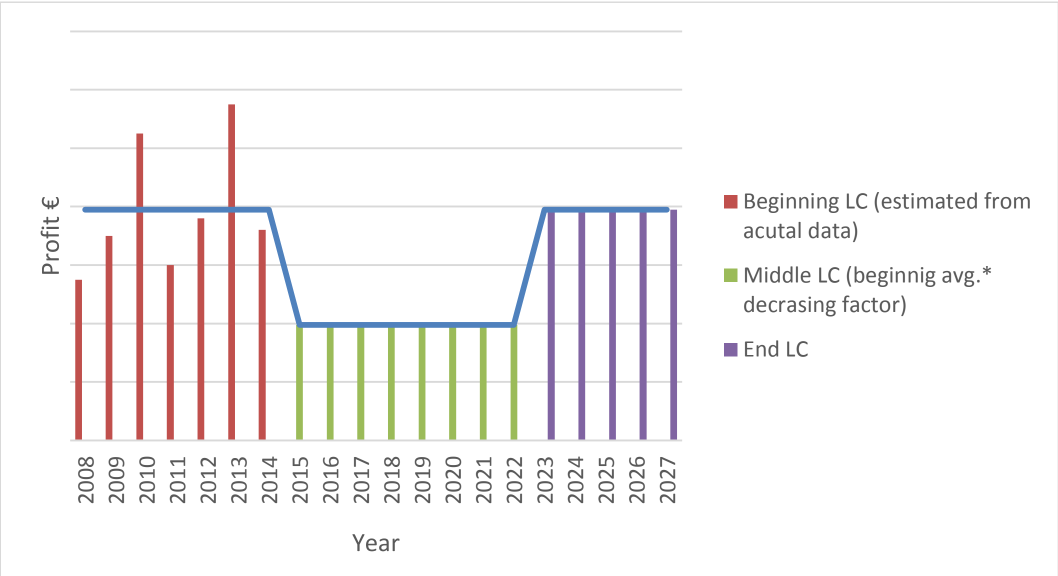


Figure 20: Illustration of the estimation method. Estimated yearly profits are in real values and the blue line is the average of profits in different parts of a life cycle.

Red bars represent actual data, green bars middle life cycle estimations and purple bars end life cycle estimations.

Figure 20 illustrates the profit estimation method with imaginary data. In the figure red bars represent the estimated profits in real values calculated from actual case data. Green bars represent the estimated middle life cycle profits and purple the end life cycle profits. The blue line represents average annual profits in each life cycle phase.

If data would be missing for example from years 2008 and 2009, then the beginning life cycle average would be calculated by using only data from years 2010-2014 (assuming all years have data available). The middle and end life cycle profits would be calculated according to this 2010-2014 average.

3.5 Analysis steps 4 & 5

Now that the annual after-sales profits are known it is possible to calculate the estimated net present value of the 20 year life cycle and to compare this with available initial sales profit data. In order to calculate the net present value a discount rate needs to be determined (see chapter 2.6.1).

3.5.1 Discount rate

Either real or nominal discount rate can be chosen for the calculation, but both have their own requirements. If a real discount rate is used, the actual data needs to be calculated without inflation and estimations need to be made in real values. If a nominal rate is used, the actual data can stay as it is, but future estimations need to be made in nominal values, which requires estimating the future inflation. The first option was chosen as finding out the past inflation and making the future estimations in real values was seen more accurate than trying to forecast inflation over a long period of time.

The inflation has been eliminated from the actual data already in step 2, so a real discount rate can be used throughout the NPV calculations. The year 0 has been chosen to be the order year for steel and WTE cranes, but the installation year for the coker cranes. This is because the coker crane projects take a long time from order to installation and using the order year as year 0 would overly decrease the NPV of these cranes.

The discount rate is chosen to be 10% as it has been used in previous internal calculations as well. Calculations were made with the real discount rate of 10% for the whole 20 year life cycle. This 10% is considered sufficient to cover uncertainty related to these profits. Equipment and initial spare part package profits are considered to be sold in year 0, so they are not discounted.

3.5.2 Initial sales data

Initial sales data was acquired for the cases. This data included the sales price of the crane with frontline's planned and actual profit-% and value of spare part package where available. The profit for the factory from the equipment sale was estimated based on general estimates from experts. Also, the profit of spare part package was estimated from the sales value. For the spare part package sales value the best available data was used, but in many cases it could not be verified that exactly these packages were sold for the crane.

Some cases were missing data, and an estimate was used instead, or that part was not taken into account. For example, some cases were missing the frontline profit-%, so an estimate was used. The coker crane and steel crane cases had no spare part package data available, so it was left out of the calculations. Therefore, the coker and steel case analyses are slightly different from the WTE case analyses.

3.5.3 Comparison of after-sales profit vs. initial sales profit

In the final step of the analysis part the net present value of after-sales profit can be compared to the initial sales profit value. The initial sales profit includes the profit from equipment sale to the frontline and factory, and the profit from spare part package sale (not coker or steel), as these are many times sold together.

Depending on the available initial sales data, the comparisons are made between after-sales profit vs. planned initial sales profit, and after-sales profit vs. actual initial sales profit. This way it is possible to see where the life cycle profits are coming from, after-sales or initial sales. This comparison also gives an insight into the importance of after-sales profits for the overall life cycle profitability of a crane. As a result, different types of cranes are plotted on a graph depicted in figure 21. The after-sales profit proportion is calculated by formula 5.

$$k = \frac{P_{AS}}{(P_I + P_{AS})} * 100 \quad (5)$$

where,

k = Proportion of after-sales profits, %

P_{AS} = Net present value of profit from after-sales, €

P_I = Initial sales profit, €.

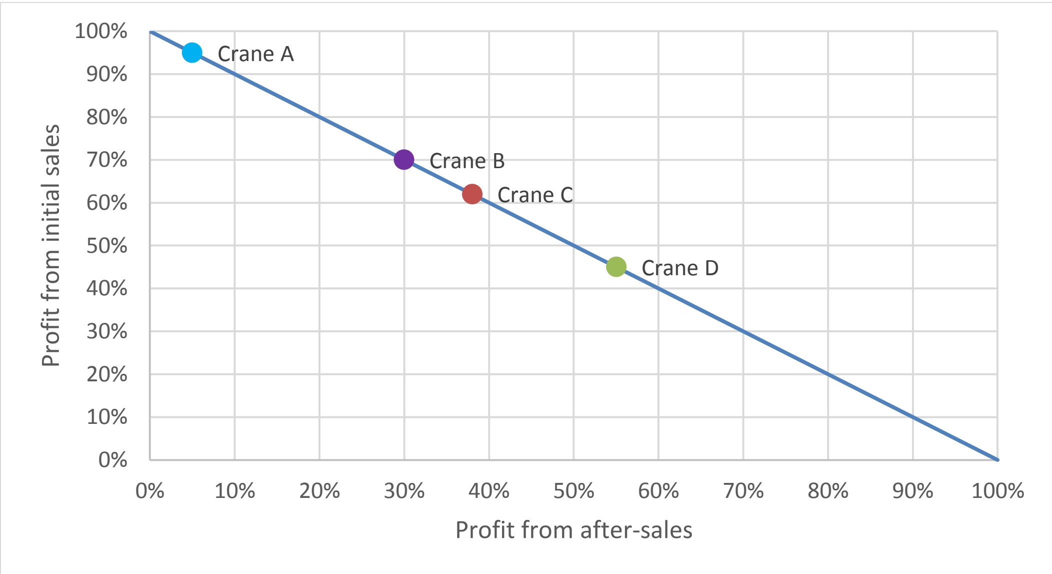


Figure 21: NPV of after-sales profit vs. initial sales profit comparison over the life cycle.

3.5.4 Sensitivity analysis variables

A sensitivity analysis needs to be done case by case to understand how different estimation errors may affect the results. Chosen parameters in the sensitivity analysis are listed in table 5.

Table 5: Sensitivity analysis variables.

Estimated overall spare part profit-%	+/- 20%
Estimated service profit-%	+/- 20%
Decreasing factor for middle life cycle profits	+/- 20%
Discount rate	+/- 20%

4 ESTIMATION TOOL

4.1 About the estimation tool

The estimation tool is supposed to be a simple Excel tool that can be used to make approximate estimations about the future profits. The tool uses data from the analyses. Table 6 lists the estimation tool steps as previously presented.

Table 6: Steps in creating the estimation tool.

Estimation tool	6.	Find out/estimate the average working cycles per year of the case cranes and calculate the estimated working cycles over the life cycle.
	7.	Divide the NPV of spare part profits by the value from (6) to get spare part sales NPV €/working cycle. This value is used by the tool to estimate the spare part after-sales profit potential.
	8.	Divide the maintenance service life cycle NPV by the value from (6) to get a NPV €/working cycle value for maintenance service after-sales profits.

The tool is a very simplified one and provides only a rough estimation of the life cycle profit potential of a crane. One of the simplifications is the use of a single driver for the overall need of spare parts and maintenance service needs. The chosen driver is working cycles.

It is also important how heavy loads the crane handles during each working cycle, but this is not taken into consideration by the tool. For example, a crane that continuously lifts overloads will be requiring more maintenance and spare parts than a crane that only lifts half-empty loads. An assumption is made that cranes operate in a similar fashion and the average load in respect to the lifting capacity is the same for all similar cranes. Ambient conditions are also assumed to be the same for all cranes operating in similar tasks in different locations. This may not be the case in reality. For these reasons the tool provides only a very approximate estimation of the future profits.

4.2 Working cycle

A crane’s tasks can be divided into working cycles. A working cycle means the process of starting an action, performing it and returning to the starting position. The working cycle phases of a waste handling crane are presented in table 7 as an example.

Table 7: Simplified working cycle for a WTE crane.

1.	Closing the grab
2.	Hoisting
3.	Travelling (bridge)
4.	Travelling (trolley)
5.	Lowering
6.	Opening the grab
7.	Hoisting
8.	Travelling (bridge)
9.	Travelling (trolley)
10.	Lowering back to starting position

At the beginning of a working cycle the grab is considered to be in the down position ready to collect waste. The grab is then closed (1) and waste is lifted (2). Simultaneously as the load is rising the trolley and the bridge start to move (3-4) towards the dumping position, for example, the hopper. When the crane has reached the wished location the load is lowered (5) and then the grab is opened to release the waste (6). Then the grab is again hoisted to the travelling height (7) and the crane moves to the next location (8-9). One cycle is over when the grab is lowered back down to its starting position (10) again.

When making estimations there should always be a cause-and-effect relationship between the level of an activity and the measured outcome (Horngren et al. 2006, p.336). According to expert judgments from crane specialists, the use of working cycles as the driver for the spare part need is economically plausible. A working cycle consists of actions that involve all moving components of a crane and therefore the number of cycles affects how much the crane components are in use and the need for spare parts and maintenance.

4.3 Estimation tool step 6

In order to create the tool the average number of working cycles done by a case crane in a year needs to be determined. This was done by using data from the crane monitoring system, or by expert judgment, depending on what information was available. An average estimation was used for all the years by the assumption that the usage of the crane in question is relatively similar from year to year.

It was determined how many working cycles on average the case cranes did in a year. Then this average was multiplied by the estimated life cycle of 20 years to get the estimated number of working cycles over the entire life cycle of the crane.

4.4 Estimation tool steps 7 and 8

In the seventh step a NPV €/working cycle can be calculated by using the previously calculated life cycle NPV € and working cycle values. Figure 22 depicts how these values from the case cranes are used by the tool.

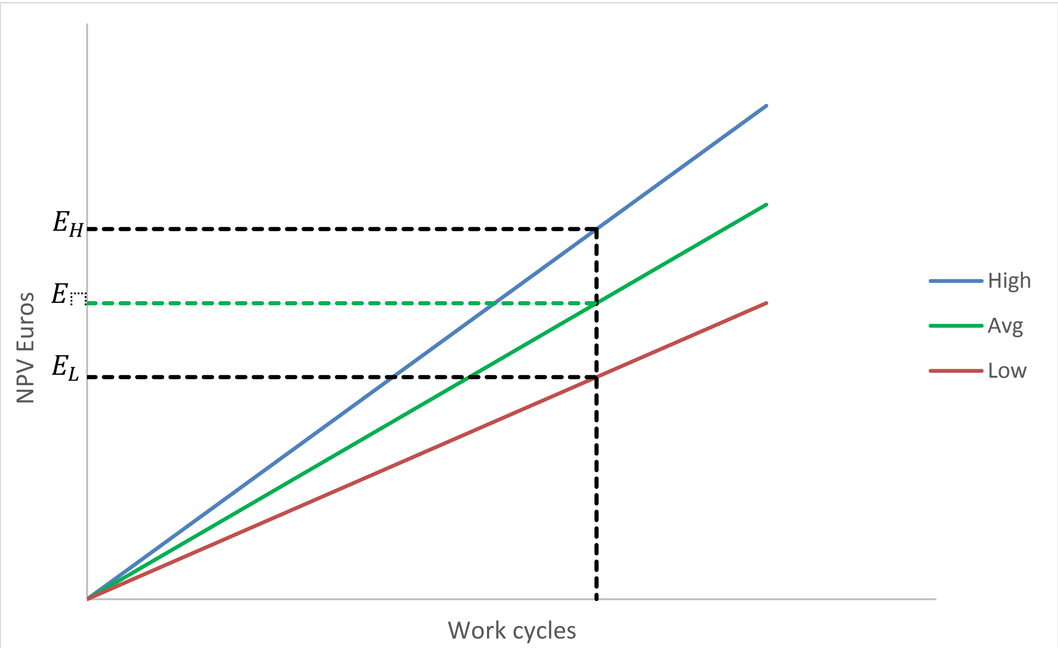


Figure 22: Spare part profit estimation.

The slope of each line is the NPV €/working cycle value and different lines depict different cases of similar cranes. By using the average of these case values an approximation can be made for the NPV €/working cycle value for that type of cranes. On the graph this approximation (E) is somewhere between the highest (E_H) and the lowest (E_L) value from the case studies.

This estimation method makes it possible to estimate the profits over a long period of time. Even though it is possible to give annual sales or profit values with the model by estimating the number of cycles in a specific year, that kind of estimate is not appropriate, since the tool is designed to give an estimate for the 20 year life cycle of the crane. Some years may be more spare part consuming than the others.

5 CASE CRANES

5.1 Waste to energy (WTE) cranes

Waste to energy (WTE) case cranes are waste handling cranes. They operate in waste bunkers that have a hopper for feeding the kettle, a tipping area for filling the bunker and a storage area for storing the waste. Waste trucks empty the waste to the tipping area of the bunker from where the crane moves the waste to the storage area or straight into the hopper for burning. An illustration of a waste bunker is depicted in figure 23.

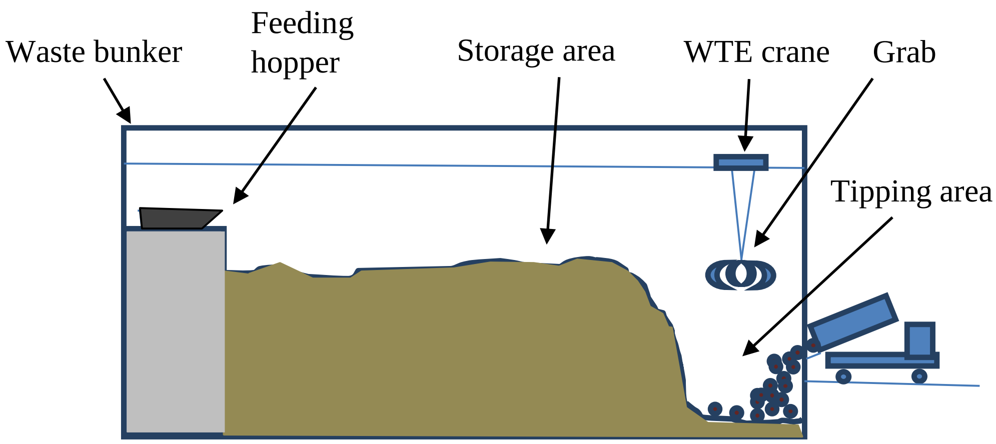


Figure 23: Illustration of a waste bunker.

Basically the crane has three tasks: to feed waste into the hopper, to keep the tipping area clear and to mix the waste storage. The crane is a critical part of the whole power plant process, since the process stops, if waste is not fed into the kettle through the hopper, unless there is an alternative (more expensive) fuel option available. Practically the crane is constantly working either feeding, mixing or stacking. The cranes can be driven manually, but often they work in autopilot.

5.1.1 Waste to energy case 1: 2 cranes in the same location

The cranes are located in Finland. These two cranes are operating in the same waste bunker, so one of the cranes is in use and the other one as a backup. This way, if one crane has a problem it is possible to switch to using the other crane. In calculations the data for these cranes were combined.

These cranes were ordered in 2007 and that is also used as the base year for the calculations, i.e. as the year where all profits are discounted to. The actual and predicted future profits are all discounted to 2007 from the period of 2007-2027.

History data for the cranes was available for 2009-2014 from the databases. Inquiries to branch managers were also made to fill in missing information. According to a questionnaire (appendix 2) made about the data reliability, the data should be quite reliable and all relevant sales should have been included. For these case cranes a large modernization was made in 2011, but the sales related to this have been removed from the data, since this kind of modernization is exceptional. Table 9 has relevant basic case data listed.

Table 9: Basic information about the case 1 cranes and their data.

Capacity	9,5 ton
Span	21 m
Order year (year 0)	2007
History data available	2009-2014
Calculated period	2007-2027
Data reliability (A=very reliable, D=very unreliable)	B (reliable)

The actual euro amounts cannot be presented due to the sensitive nature of the information. Therefore the research question 2 is answered by presenting the NPV of estimated after-sales profits as a percentage of the overall profits. In figure 24 it is presented what percentage of the overall profits come from after-sales and what percentage of the profits come from initial sales. For more detailed explanation of how after-sales profits were calculated, see chapter 3.

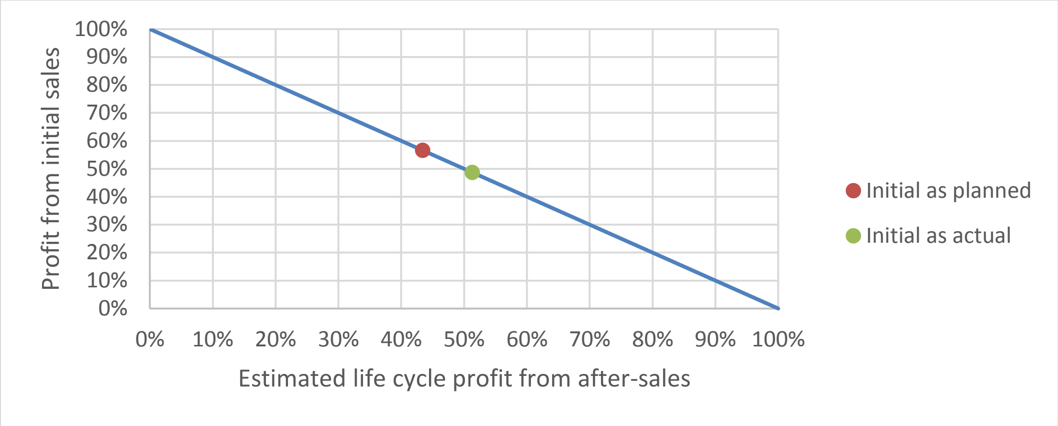


Figure 24: Initial sales profit vs. after-sales profit of case 1 cranes.

As presented in figure 24, the estimated after-sales profits are 44% and the planned initial profit 56% of the overall life cycle profits. If estimated life cycle after-sales profits are compared to the actual initial sales profits, then profits are 52% after-sales and 48% actual initial sales. Either way, a significant proportion of the profits come from after-sales.

To analyze what kind of effects the used estimations have on the after-sales NPV a sensitivity analysis was carried out. With a sensitivity analysis it is possible to investigate how a change in one variable affects the results. Table 10 presents the results of a sensitivity analysis with the four chosen variables.

Table 10: Sensitivity analysis of the net present value of estimated after-sales profits for case 1 cranes.

	-20%	**-10%**	**-5%**	**+5%**	**+10%**	**+20%**
Estimated overall spare part profit-%	-11,54 %	-5,77 %	-2,89 %	2,89 %	5,77 %	11,54 %
Estimated service profit-%	-8,30 %	-4,15 %	-2,08 %	2,08 %	4,15 %	8,30 %
Decreasing factor for middle life cycle profits	-5,35 %	-2,68 %	-1,34 %	1,34 %	2,68 %	5,35 %
Discount rate	16,90 %	7,96 %	3,87 %	-3,65 %	-7,11 %	-13,49 %

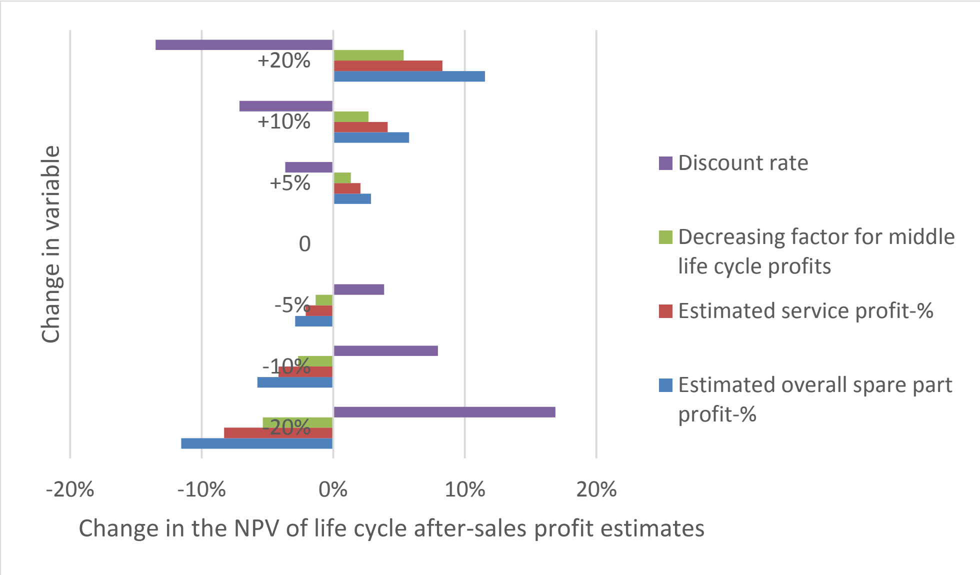


Figure 25: Sensitivity analysis of case 1 cranes.

Based on the sensitivity analysis results presented in table 10 and figure 25, the used discount rate is the most critical factor affecting the life cycle NPV of profit estimates. After discount rate the second most important variable is the estimated overall spare part percentage. Changes in the decreasing factor presented in formula 4 (chapter 3.4) have a relatively small impact on the end results, unless differences to reality are large.

Now, if we reconsider the plotting in figure 24 and assume a 20% error in the spare part overall profit percentage, which has the biggest effect on the after-sales NPV excluding the discount rate, we would get the plot presented in figure 26. According to this analysis it would seem the NPV of the after-sales life cycle profit of this case crane would be around 41-47% of the complete life cycle profits of the crane, when compared to the planned new equipment sales profit. If compared to the actual initial sales profits, the proportion of after-sales profits would be much higher.

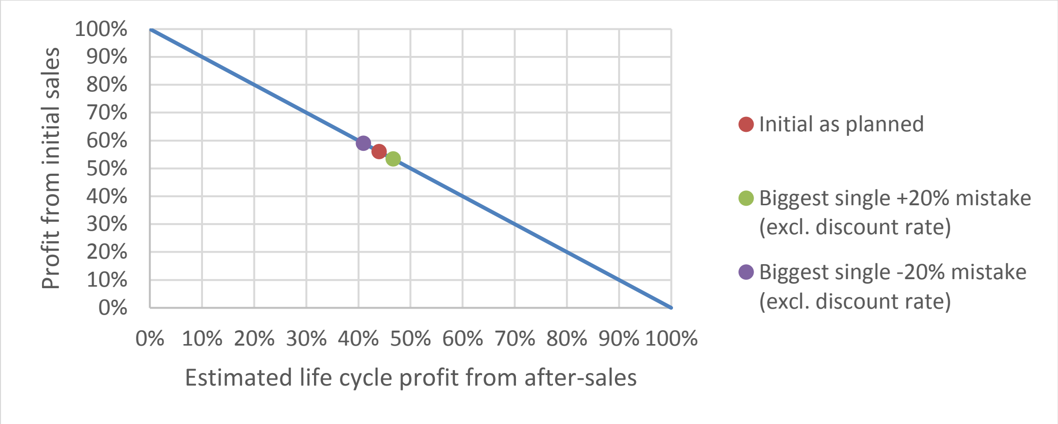


Figure 26: Initial sales profit vs. after-sales profit of case 1 cranes with positive and negative after-sales estimate error.

Figure 27 presents where the after-sales profits are estimated to be coming from. According to the life cycle estimates created, spare parts account for 58% and maintenance services for 42% of the NPV of after-sales life cycle profits. If the crane's maintenance was taken care of by some other company, only the spare part profits could be assumed to be gained, and a proportion of these could be lost as well, since some parts now ordered from Konecranes might be ordered from elsewhere.

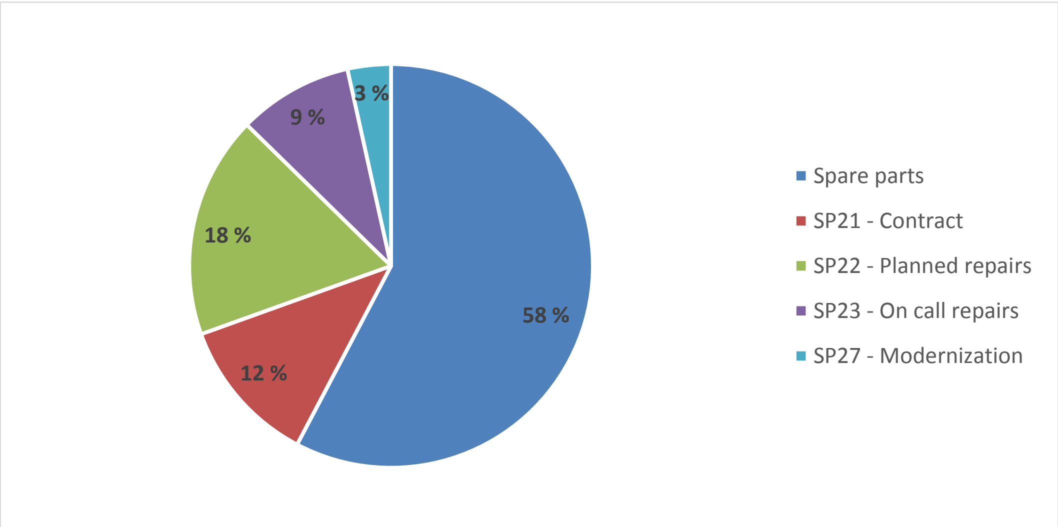


Figure 27: Proportions of estimated after-sales NPV life cycle profit of case 1 cranes.

5.1.2 Waste to energy case 2: one crane

The WTE crane is located in Finland. It is the only crane operating in the bunker. This makes reliability very important as there is no backup crane, if it is broken.

The crane was ordered in 2007 which is also used as the base year for the calculations, i.e. as the year where all profits are discounted to. The actual and predicted future profits are all discounted to 2007 from the period of 2007-2027.

History data for the crane was available for 2009-2014 from the databases. Inquiries to branch managers were also made to fill in missing information. According to a questionnaire (appendix 2) made about the data reliability, the data should be quite reliable and all relevant sales should have been included. Table 11 has relevant basic case data listed.

Table 11: Basic info about the case 2 crane and its data.

Capacity	7,5 ton
Span	26 m
Order year (year 0)	2007
History data available	2009-2014
Calculated period	2007-2027
Data reliability (A=very reliable, D=very unreliable)	B (reliable)

The actual euro amounts cannot be presented due to the sensitive nature of the information. Therefore the research question 2 is answered by presenting the NPV of estimated after-sales profits as a percentage of the overall profits. In figure 28 it is presented what percentage of the overall profits come from after-sales and what percentage of the profits come from initial sales. For more detailed explanation of how after-sales profits were calculated, see chapter 3.

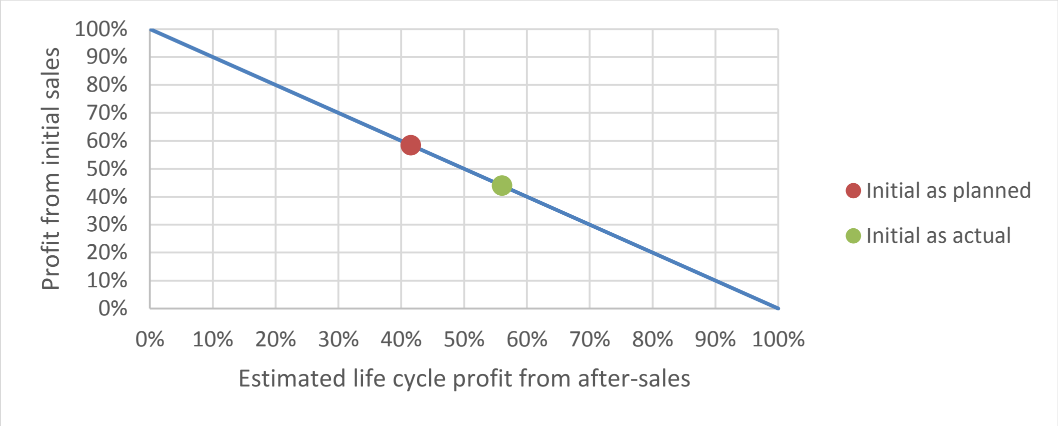


Figure 28: Initial sales profit vs. after-sales profit of case 2 crane.

As presented in figure 28 the estimated after-sales profits are 41% and the planned initial profit 59% of the overall life cycle profits. If estimated life cycle after-sales profits are compared to the actual initial sales profits, then profits in this case are 56% from after-sales and 44% from initial sales. Either way, a significant proportion of the profits come from after-sales.

To analyze what kind of effects the used estimations have on the after-sales NPV a sensitivity analysis was carried out. With a sensitivity analysis it is possible to investigate how a change in one variable affects the results. Table 12 and figure 29 present the results of a sensitivity analysis with the four chosen variables.

Table 12: Sensitivity analysis of the net present value of estimated after-sales profits for case 2 crane.

	-20%	**-10%**	**-5%**	**+5%**	**+10%**	**+20%**
Estimated overall spare part profit-%	-8,08 %	-4,04 %	-2,02 %	2,02 %	4,04 %	8,08 %
Estimated service profit-%	-11,92 %	-5,96 %	-2,98 %	2,98 %	5,96 %	11,92 %
Decreasing factor for middle life cycle profits	-5,26 %	-2,63 %	-1,32 %	1,32 %	2,63 %	5,26 %
Discount rate	18,33 %	8,62 %	4,19 %	-3,95 %	-7,69 %	-14,56 %

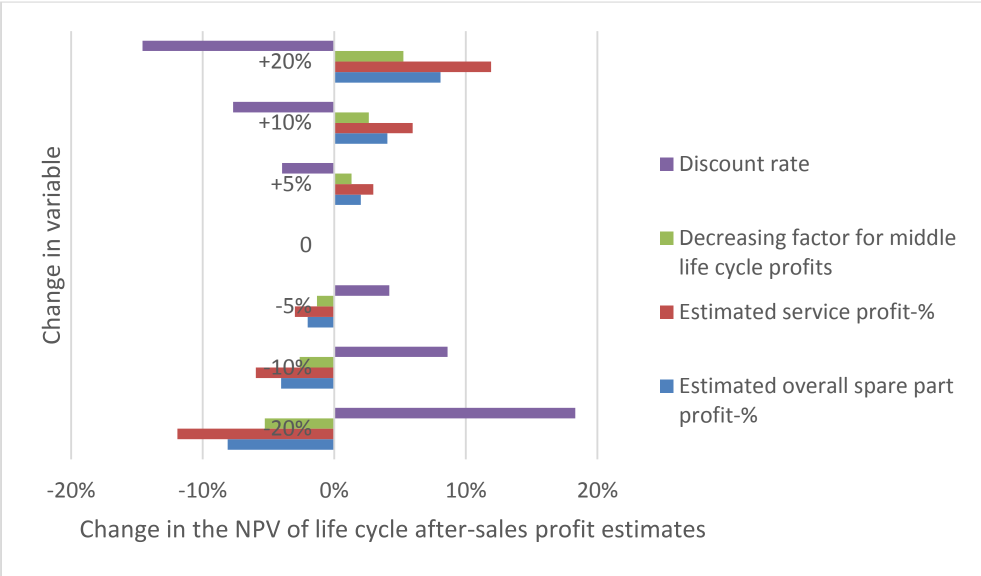


Figure 29: Sensitivity analysis of case 2 crane.

Based on the sensitivity analysis results presented in table 12 and figure 29, the used discount rate is the most critical factor affecting the life cycle NPV of profit estimates. After the discount rate the second most important variable is the estimated service labor profit percentages. Changes in the overall spare part profit percentage and the decreasing factor presented in formula 4 (chapter 3.4) have a relatively small impact on the end results, unless differences to reality are large.

Now, if we reconsider the plotting in figure 28 and assume a 20% error in the service profit percentages, which has the biggest effect on the after-sales NPV excluding the discount rate, we would get the plot presented in figure 30. According to this analysis it would seem the NPV of the after-sales life cycle profit of this case crane would be around 38-44% of the complete life cycle profits of the crane, when compared to the planned new equipment sales profit. If compared to the actual initial sales profits, the proportion of after-sales profits would be much higher.

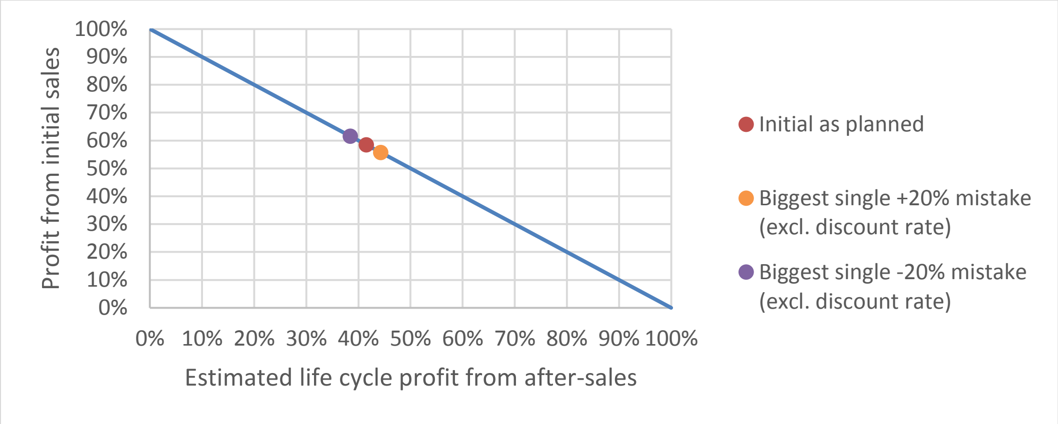


Figure 30: Initial sales profit vs. after-sales profit of case 2 crane with positive and negative after-sales estimate error.

Figure 31 presents where the after-sales profits are estimated to be coming from. According to the life cycle estimates created, spare parts account for 40% and maintenance services for 60% of the NPV of after-sales life cycle profits. In case the crane's maintenance was taken care of by some other company, only the spare part profits could be assumed to be gained, and a proportion of these could be lost as well without a maintenance contract, since some parts now ordered from Konecranes might be ordered from elsewhere.

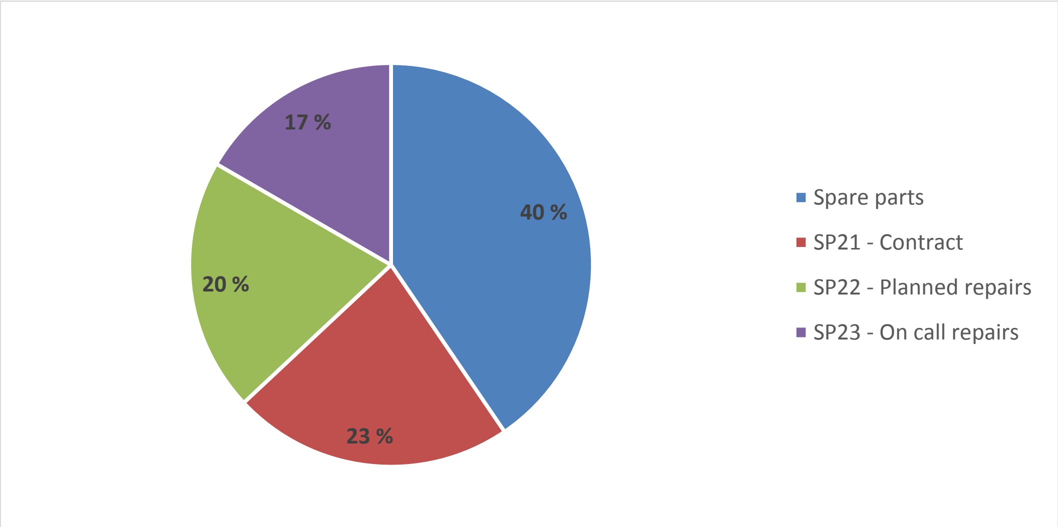


Figure 31: Proportions of estimated after-sales NPV life cycle profit of case 2 crane.

5.1.3 Waste to energy case 3: 2 cranes in the same location

The case 3 WTE cranes are located in the United Kingdom. The two cranes operate in the same waste bunker, so one of the cranes is in use and the other one as a backup. This way, if one crane has a problem it is possible to switch to using the other crane. In calculations the data for these cranes were combined.

These cranes were ordered in 2009 and that is also used as the base year for the calculations, i.e. as the year where all profits are discounted to. The actual and predicted future profits are all discounted to 2009 from the period of 2009-2029.

History data for the cranes was available for 2011-2014 from the data bases. Inquiries to branch manager were also made to fill in the missing information. According to a questionnaire made about the data reliability the data should be quite reliable, however there are possibilities for having excess sales included, because the history data did not have the cranes clearly specified. It is also possible that some sales were not included though. Table 13 has basic case data listed.

Table 13: Basic information about the case 3 cranes and their data.

Capacity	25 ton
Span	21,5 m
Order year (year 0)	2009
History data available	2011-2014
Calculated period	2009-2029
Data reliability (A=very reliable, D=very unreliable)	B (reliable)

The actual euro amounts cannot be presented due to the sensitive nature of the information. Therefore the research question 2 is answered by presenting the NPV of estimated after-sales profits as a percentage of the overall profits. In figure 32 it is presented what percentage of the overall profits come from after-sales and what percentage of the profits come from initial sales. For more detailed explanation of how after-sales profits were calculated, see chapter 3.

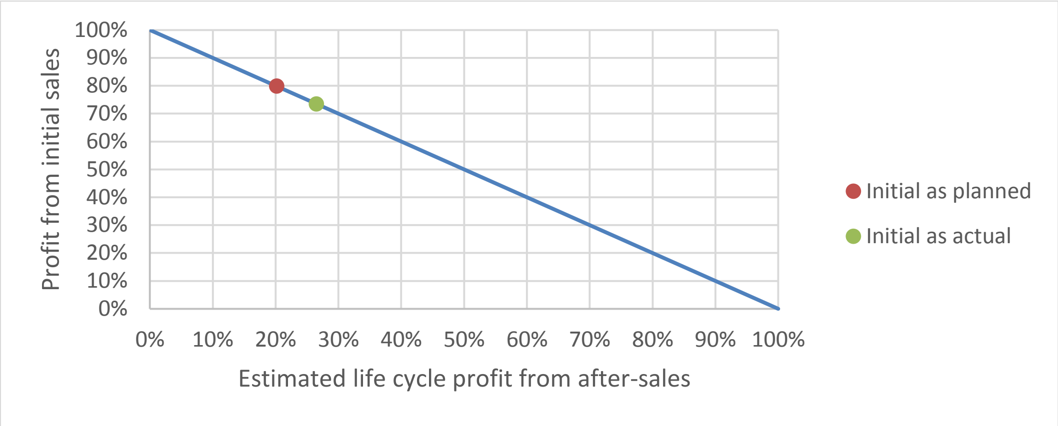


Figure 32: Initial sales profit vs. after-sales profit of case 3 cranes.

As presented in figure 32 the estimated after-sales profits are 20% and the planned initial profit 80% of the overall life cycle profits. If estimated life cycle after-sales profits are compared to the actual initial sales profits, then profits from after-sales account for 26% and initial sales 74% of the overall life cycle profits. In percentage terms this is not as high as with the two other WTE case cranes, but still significant.

To analyze what kind of effects the used estimations have on the after-sales NPV a sensitivity analysis was carried out. With a sensitivity analysis it is possible to investigate how a change in one variable affects the results. Table 14 and figure 33 present the results of a sensitivity analysis with the four chosen variables.

Table 14: Sensitivity analysis of the net present value of estimated after-sales profits for case 3 cranes.

	-20%	-10%	-5%	+5%	+10%	+20%
Estimated overall spare part profit-%	-10,31 %	-5,15 %	-2,58 %	2,58 %	5,15 %	10,31 %
Estimated service profit-%	-9,69 %	-4,85 %	-2,42 %	2,42 %	4,85 %	9,69 %
Decreasing factor for middle life cycle profits	-6,63 %	-3,31 %	-1,66 %	1,66 %	3,31 %	6,63 %
Discount rate	17,01 %	8,01 %	3,89 %	-3,68 %	-7,15 %	-13,56 %

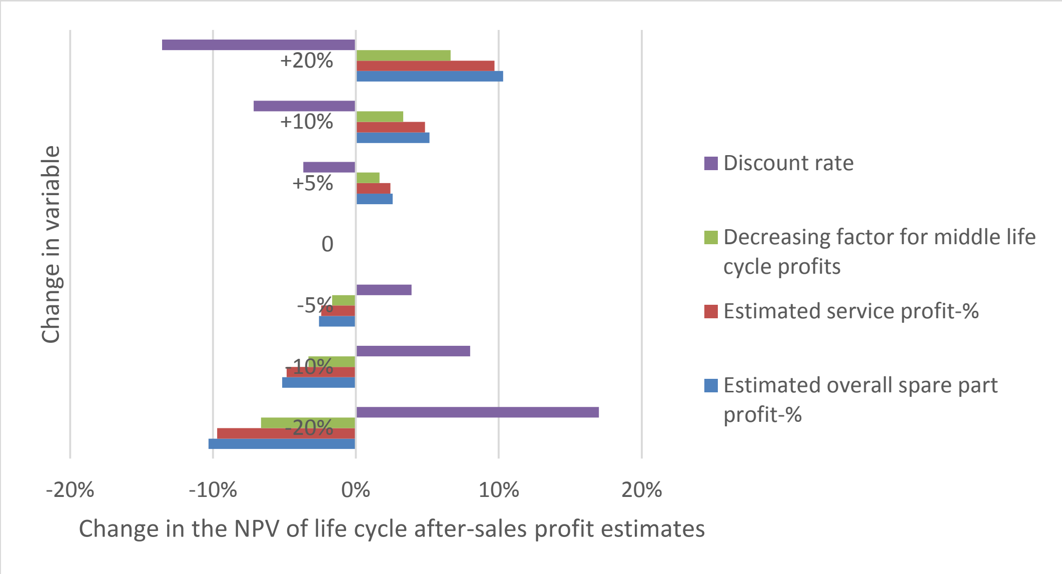


Figure 33: Sensitivity analysis of case 3 cranes.

Based on the sensitivity analysis results presented in table 13 and figure 33, discount rate is the most critical factor affecting the life cycle NPV of profit estimates. After the discount rate the second most important variable is the estimated overall spare part profit percentage together with service profit percentage. Changes in the decreasing factor presented in formula 4 (chapter 3.4) has smaller impact on the end results, unless differences to reality are large.

Now, if we reconsider the plotting in figure 32 and assume a 20% error in the estimated service profit percentages, which has the biggest effect on the after-sales NPV excluding the discount rate, we would get the plot presented in figure 34.

According to this analysis it would seem the NPV of the after-sales life cycle profits of these case cranes would be around 18-22% of the complete life cycle profits of the crane, when compared to the planned initial sales profit. If compared to the actual initial sales profits, the proportion of after-sales profits would be much higher.

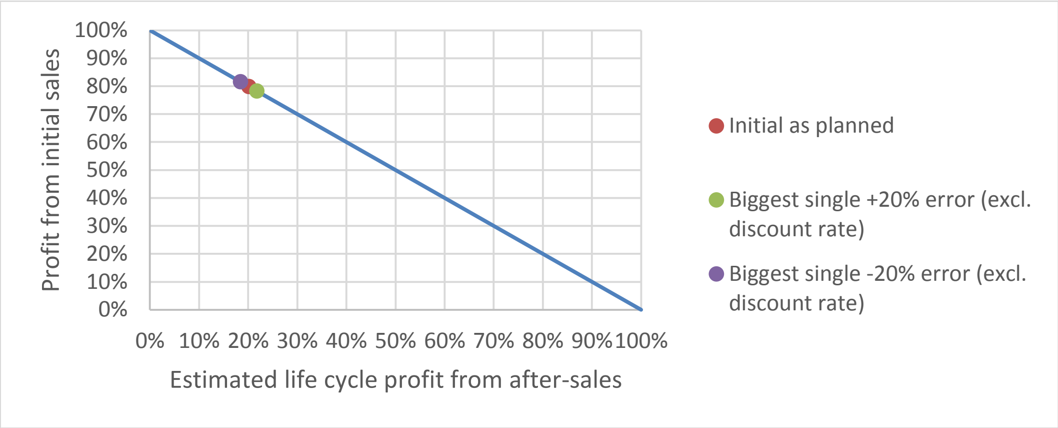


Figure 34: Initial sales profit vs. after-sales profit of case 3 cranes with positive and negative after-sales estimate errors.

Figure 35 presents where the after-sales profits are estimated to be coming from. According to the life cycle estimates created, spare parts account for 52% and maintenance services for 48% of the NPV of after-sales life cycle profits. In case the crane's maintenance was taken care of by some other company, only the spare part profits could be assumed to be gained, and a proportion of these could be lost as well without a maintenance contract, since some parts now ordered from Konecranes might be ordered from elsewhere.

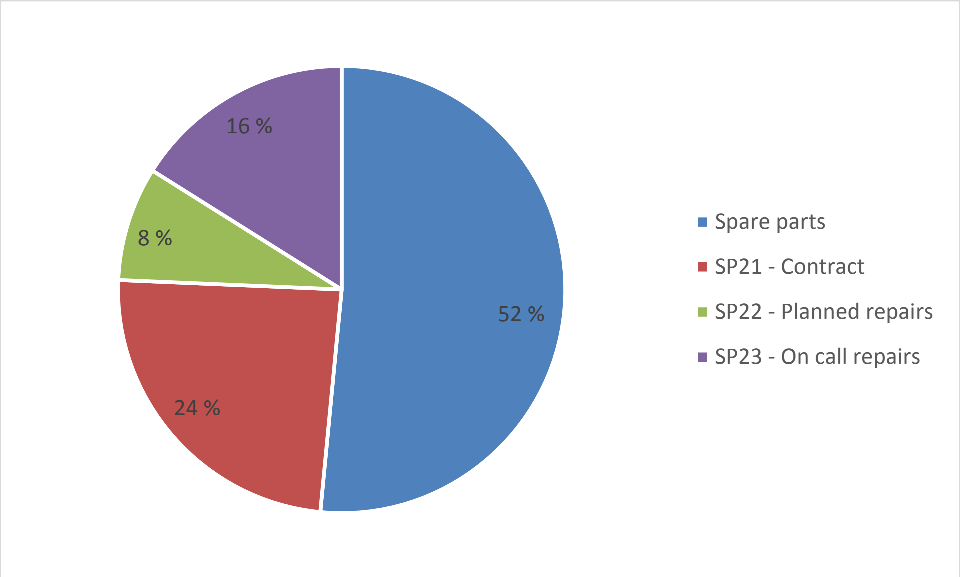


Figure 35: Proportions of estimated after-sales NPV life cycle profit of case 3 cranes.

5.2 Steel handling crane

Steel making is a multistep complex process that requires a variety of different kinds of cranes in different tasks. There are cranes for charging and scrap, ladle, slab and coil handling. In this work there is only one steel case crane, and it is a charging crane. Figure 36 presents an illustration of a steel factory layout.

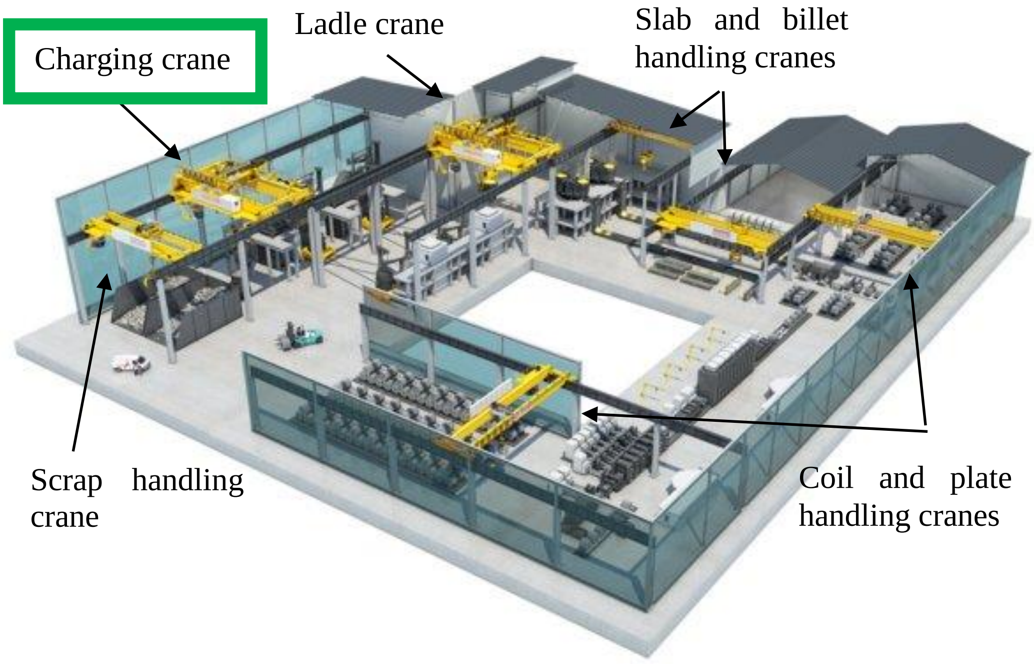


Figure 36: Steel factory layout (Konecranes Steel book 2013, 18)

A charging crane transports steel into the furnace. The transported steel can be in the form of scrap or liquid. When charging the furnace the crane can be exposed to flames and high temperatures. The cranes are a critical part of the entire steel making process, so high reliability is required.

5.2.1 Steel handling crane case 4: a charging crane

The case 4 charging crane is located in Finland. The crane was ordered in 2005 and that is also used as the base year for the calculations. The actual and predicted future profits are all discounted to 2005 from the period of 2005-2025.

History data for the crane was available for 2006-2014, though some of these years may have been missing part of the actual sales. The spare part data was missing price information, so the 2014 prices of the known spare parts were used. According to a questionnaire (appendix 2) made about the data reliability, the data should be reliable, but there may be some spare part sales missing from the used data, as the customer makes some orders directly to the Konecranes crane part center. Table 15 has basic crane data listed.

Table 15: Basic information about the case 4 crane.

Capacity	110/40 ton
Order year (year 0)	2005
History data available	2006-2014
Calculated period	2005-2025
Data reliability (A=very reliable, D=very unreliable)	A
Additional info:	No spare part package data included

Figure 37 presents what percentage of the overall profits come from after-sales and what percentage of the profits come from initial sales. For more detailed explanation of how after-sales profits were calculated, see chapter 3.

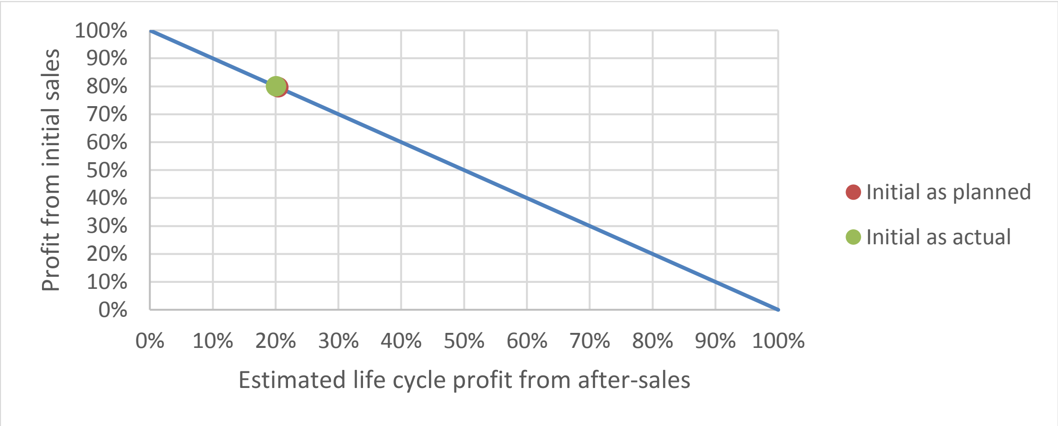


Figure 37: Initial sales profit vs. after-sales profit of case 4 crane.

As presented in figure 37, the estimated after-sales profits are 20% and the planned initial profits 80% of the overall life cycle profits. In this case the actual and planned initial sales were almost the same.

To analyze what kind of effects the used estimations have on the after-sales NPV a sensitivity analysis was carried out. With a sensitivity analysis it is possible to investigate how a change in one variable affects the results. Table 16 and figure 38 present the results of a sensitivity analysis with the four chosen variables.

Table 16: Sensitivity analysis of the net present value of estimated after-sales profits for case 4 crane.

	-20%	**-10%**	**-5%**	**+5%**	**+10%**	**+20%**
Estimated overall spare part profit-%	-4,58 %	-2,29 %	-1,15 %	1,15 %	2,29 %	4,58 %
Estimated service profit-%	-15,42 %	-7,71 %	-3,85 %	3,85 %	7,71 %	15,42 %
Decreasing factor for middle life cycle profits	-1,93 %	-0,96 %	-0,48 %	0,48 %	0,96 %	1,93 %
Discount rate	16,39 %	7,72 %	3,75 %	-3,55 %	-6,91 %	-13,10 %

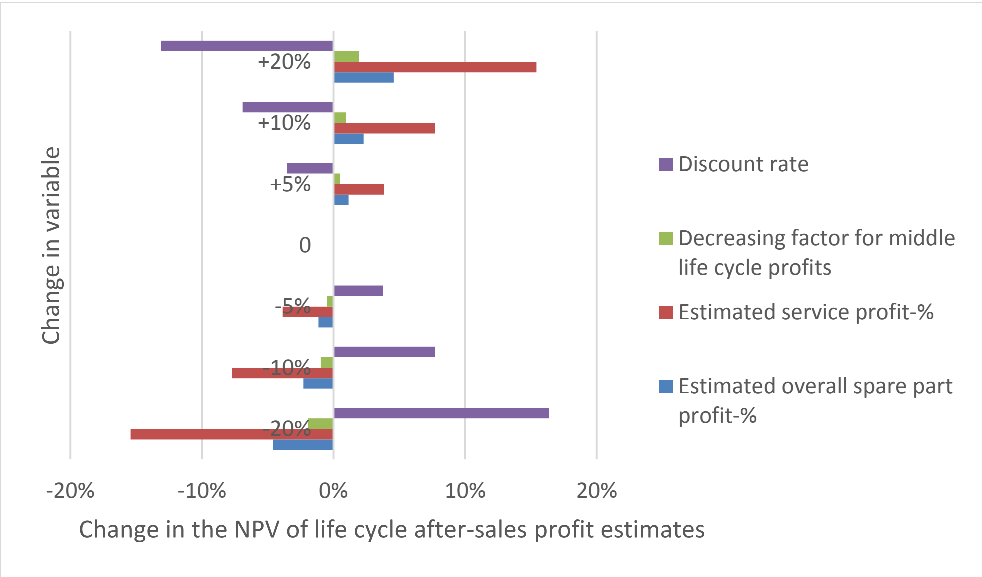


Figure 38: Sensitivity analysis of case 4 crane.

Based on the sensitivity analysis results presented in table 16 and figure 38, the estimated service labor profit percentages are the most critical factor affecting the overall life cycle NPV of profit estimates. The second is the used discount rate. Changes in the overall spare part profit percentage and the decreasing factor presented in formula 4 (chapter 3.4) have a relatively small impact on the end results, unless differences to reality are large.

Now, if we reconsider the plotting in figure 37 and assume a 20% error in service profit percentages, which has the biggest effect on the after-sales NPV, we would get the plot presented on figure 39. According to this analysis, it would seem the NPV of the after-sales life cycle profit of this case crane would be around 18-23% of the complete life cycle profits of the crane, when compared to the planned new equipment sales profit.

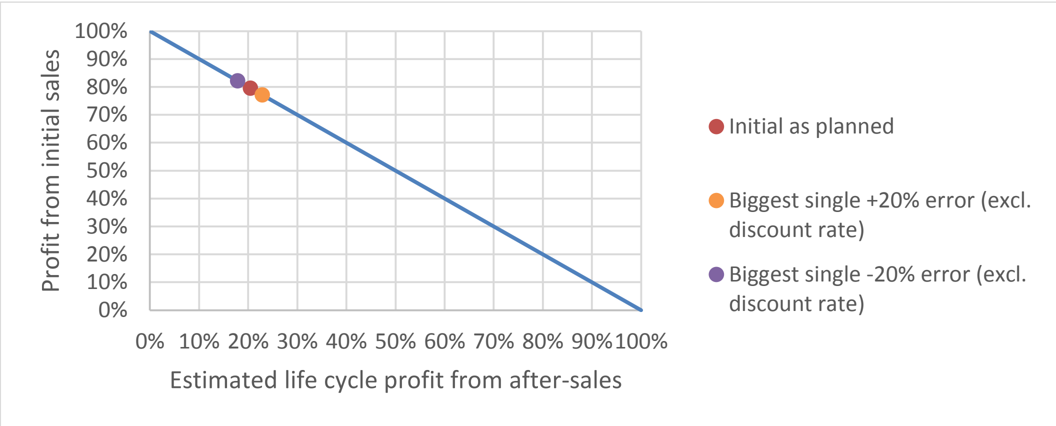


Figure 39: Initial sales profit vs. after-sales profit of case 4 crane with positive and negative after-sales estimate error.

Figure 40 presents where the after-sales profits are estimated to be coming from. According to the life cycle estimates created, spare parts account for only 23% and maintenance services for 77% of the NPV of after-sales life cycle profits. If the crane’s maintenance was taken care of by some other company, only the spare part profits could be assumed to be gained, and a proportion of these could be lost as well, since some parts now ordered from Konecranes might be ordered from elsewhere.

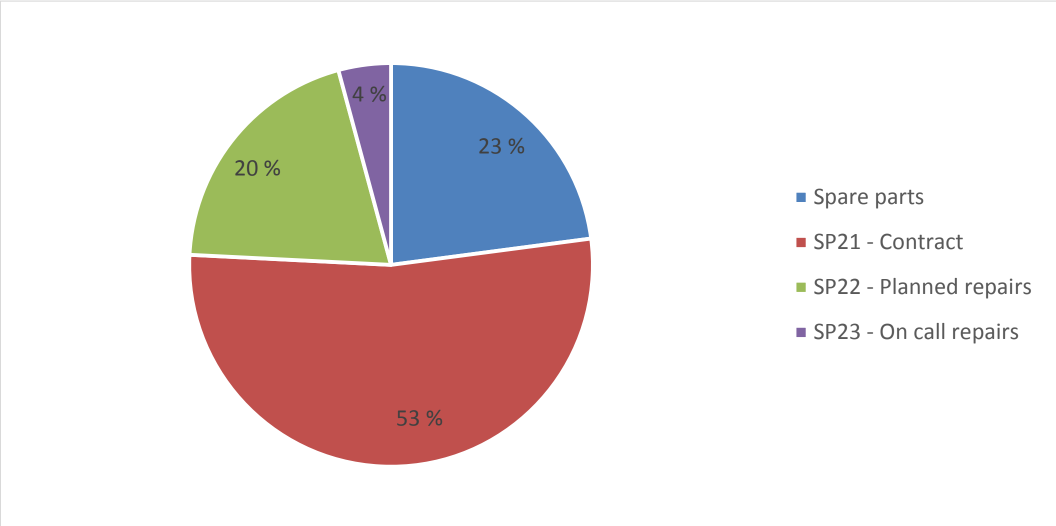


Figure 40: Proportions of estimated after-sales NPV life cycle profit of case 4 crane.

5.3 Coker cranes

Coker cranes are used as a part of oil refining process. Their task is to handle petroleum coke that is produced in the delayed coker units. Coke drums discharge the coke into a coke pit. The cranes handle this coke into intermediate storage and to a hopper for further processing. (Konecranes b. 2014) Figure 41 provides a simplified illustration of a coke pit and a coker crane.

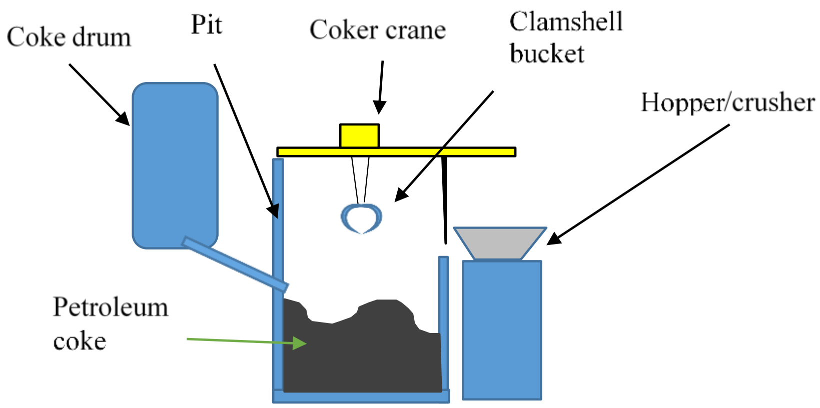


Figure 41: Simplified illustration of coker crane working environment. The crane in the picture is a single leg gantry crane with cantilever.

The working environment of coker cranes is challenging. The environment is corrosive and there is lots of coke dust present. These cranes are also operated round the clock as coke is being moved to drying pad and to the hopper. Reliability is important and downtime needs to be minimized.

For this thesis three different coker cranes were studied. Each of them had limited data availability. Two of these cranes only had short histories available, as they had been installed in 2011 and 2012. The third crane was installed in 2006, so it had a longer history, but data before 2009 was not available. Also, there were no data available about the sold spare part packages for the cranes. A decision was made to only include the third crane in the analysis part.

All of the three cranes are located in India and they have high level service contracts. In addition to maintenance also operating the crane is included in the contract. This increases the proportion of SP21's proportion of the after-sales profits in the analysis. This is important to understand when considering the results, since it increases service profits and the percentage of profits from services of the overall net present value of after-sales profits. Without this high level contract the profits would be lower. Instead of the order year, the installation year was chosen to be the base year in the calculations.

5.3.1 Case 5: a coker crane

The case 5 coker crane is in India. The crane was ordered in 2003 and installed in 2006. The installation year is used as the base year for the calculations. The actual and predicted future profits are all discounted to 2006 for the period of 2006-2026.

History data for the crane was available for 2009-2014. The lack of data over the first years of the life cycle has a decreasing effect on the after-sales profit results of this analysis. The service contract value was estimated for 2007-2009 based on the available data with the assumption that it has been similar, but other possible sales and profits over this time were not included. Data reliability of the data before 2012 could not be verified. In table 17 the basic crane data is presented.

Table 17: Basic information about the case 5 crane.

Capacity	44 ton
Span	22,5m
Order year	2001
Installed (year 0 in calculations)	2006
History data available	2009-07/2014
Calculated period	2006-2026
Data reliability (A=very reliable, D=very unreliable)	No questionnaire
Additional info:	No spare part package data included

In figure 42 it is presented what percentage of the overall profits come from after-sales and what percentage of the profits come from initial sales. For more detailed explanation of how after-sales profits were calculated, see chapter 3. Case specific factors affecting the result are: no spare part package data (lower initial sales profit-%), lack of spare part and service data for 2006-2009 (lower after-sales profit), high level of service contract (high SP21 proportion of after-sales profits). In addition, the 2014 data is not for the whole year.

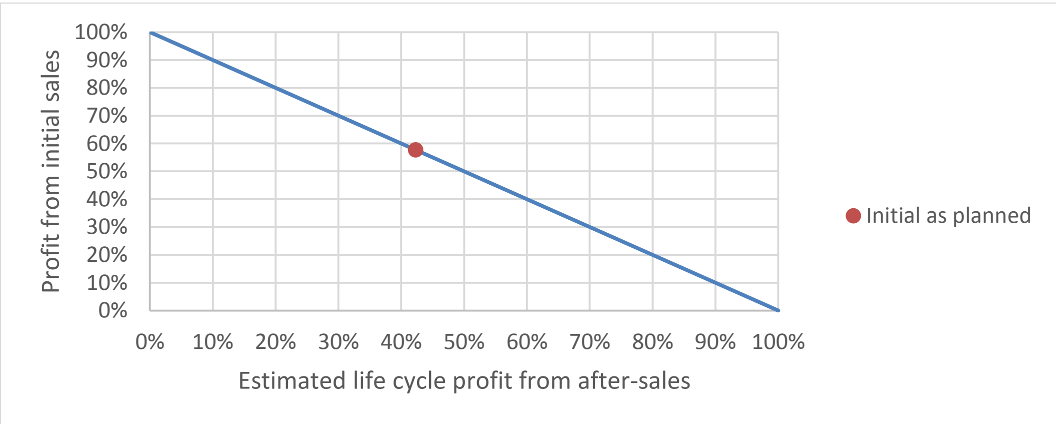


Figure 42: Initial sales profit vs. after-sales profit of case 5 crane.

As presented in figure 42, the estimated after-sales profits are 42% and the planned initial profit 58% of the overall life cycle profits. In this case there was no actual data for the initial sales available, so only planned values were used. It should also be noted that the after-sales data was lacking data for the first years of the life cycle, decreasing the after-sales profit proportion.

To analyze what kind of effects the used estimations have on the after-sales NPV a sensitivity analysis was carried out. With a sensitivity analysis it is possible to investigate how a change in one variable affects the results. Table 18 and figure 43 present the results of a sensitivity analysis with the four chosen variables.

Table 18: Sensitivity analysis of the net present value of estimated after-sales profits for case 5 crane.

	-20%	-10%	-5%	+5%	+10%	+20%
Estimated overall spare part profit-%	-11,79 %	-5,89 %	-2,95 %	2,95 %	5,89 %	11,79 %
Estimated service profit-%	-7,11 %	-3,55 %	-1,78 %	1,78 %	3,55 %	7,11 %
Decreasing factor for middle life cycle profits	-4,13 %	-2,06 %	-1,03 %	1,03 %	2,06 %	4,13 %
Discount rate	19,57 %	9,19 %	4,46 %	-4,20 %	-8,16 %	-15,42 %

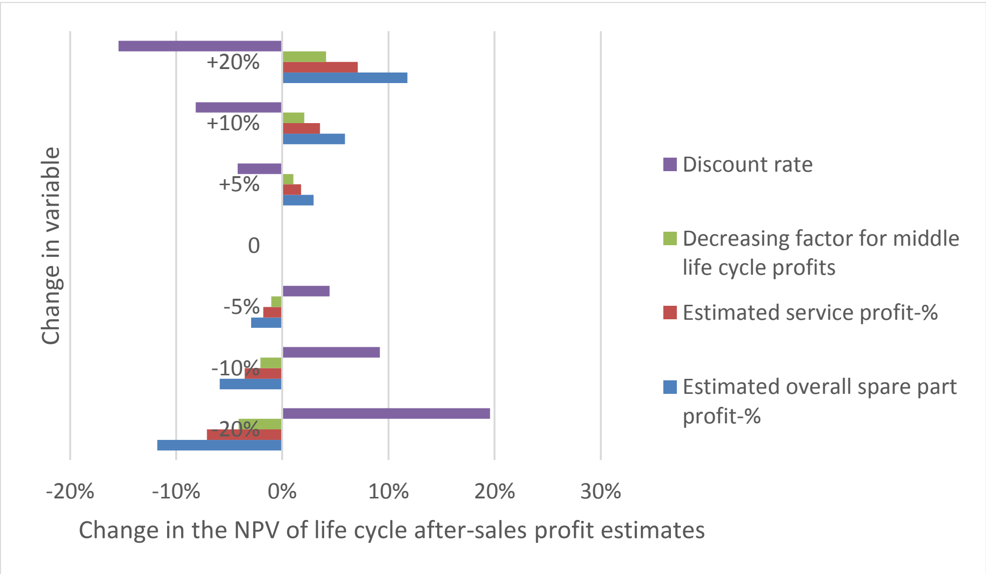


Figure 43: Sensitivity analysis of case 5 crane.

Based on the sensitivity analysis results presented in table 18 and figure 43, the used discount rate is the most critical factor affecting the overall life cycle NPV of profit estimates. The estimated overall spare part profit and service profit percentages have also a big influence on the outcome. Changes in the decreasing factor presented in formula 4 (chapter 3.4) has a relatively small impact on the end results, unless differences to reality are large.

Now, if we reconsider the plotting in figure 42 and assume a 20% error in the overall spare part profit percentage, which has the biggest effect on the after-sales NPV, we would get the plot presented in figure 44. According to this analysis it would seem the NPV of the after-sales life cycle profit of this case crane would be around 39-45% of the complete life cycle profits of the crane, when compared to the planned new equipment sales profit.

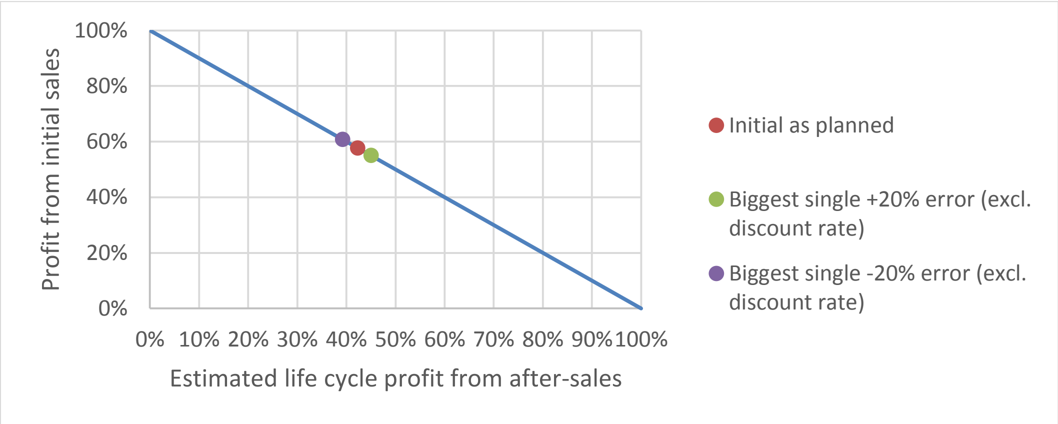


Figure 44: Initial sales profit vs. after-sales profit of case 5 crane with positive and negative after-sales estimate error.

Figure 45 presents where the after-sales profits are estimated to be coming from. According to the life cycle estimates created, spare parts account for 59% and maintenance services for 41% of the NPV of after-sales life cycle profits. The service sales are mainly from the contract. If the crane’s maintenance was taken care of by some other company, only the spare part profits could be assumed to be gained, and a proportion of these could be lost as well, since some parts now ordered from Konecranes might be ordered from elsewhere.

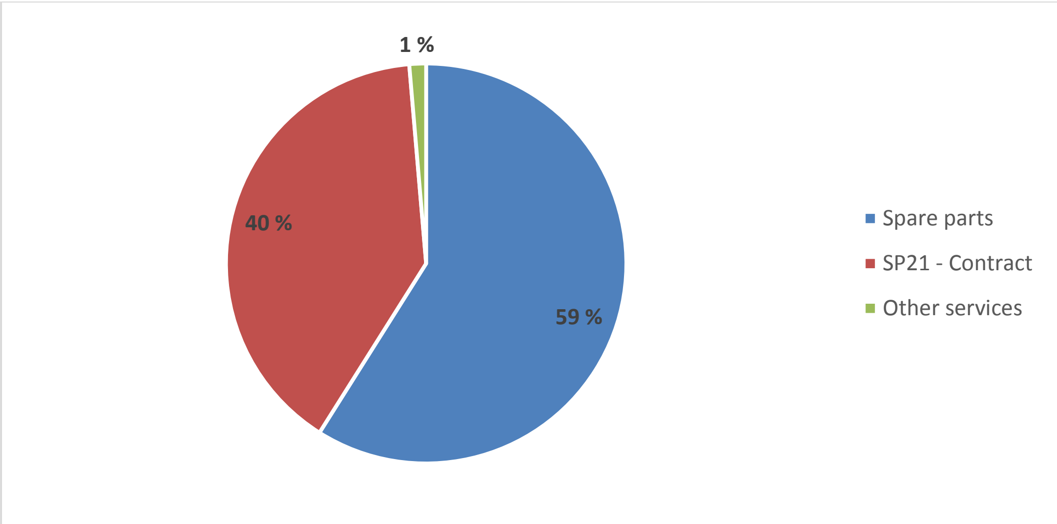


Figure 45: Proportions of estimated after-sales NPV life cycle profit of case 5 crane.

6 RESULTS AND CONCLUSION

6.1 Combined results from the analysis

Combined results are presented in figure 46. In the chosen cases the after-sales proportion of profits is between 20% and 44% of the total calculated life cycle profits when compared to the planned initial sales profits. All the chosen case cranes have had and are expected to have significant profits from the after-sales. The coker crane case has the difference that no spare part package data was included (lower initial sales profit-%) and the after-sales data was missing for the first three years of the analysis (lower after-sales profit-%), these two do not cancel each other completely, but at least have an opposite effect on the proportional results. When considering the monetary values of these results (not presented in the thesis) the NPV of after-sales profits can be assumed to be a conservative estimate.

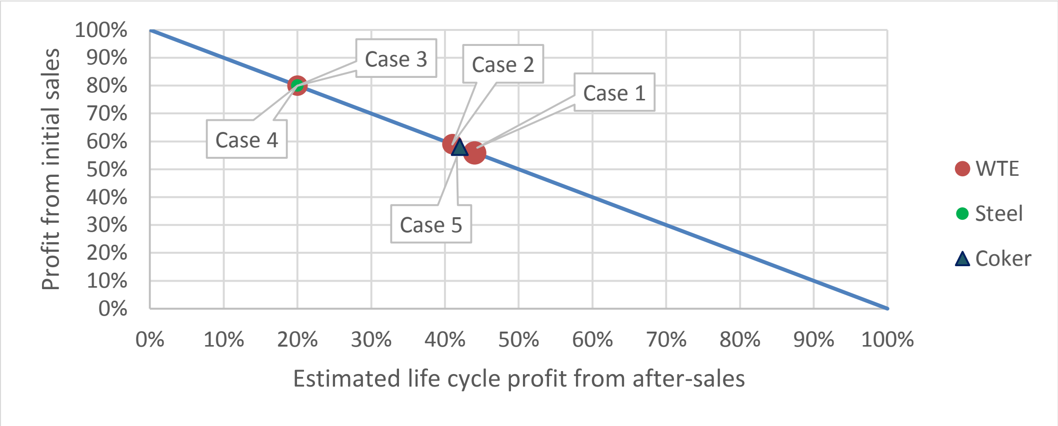


Figure 46: Combined results from the case analyses.

The results of the WTE case analyses seem to support each other. According to these case analyses the expected after-sales profits are both similar in each case and also significant in value.

In figure 47 an observed relationship between the initial sales value and the percentage of after-sales of the total life cycle profits of waste to energy cranes is presented. The image serves the purpose of explaining how initial sales value and profit margin affect the results in figure 46. As life cycle after-sales profits do not follow sales value of the crane, in the WTE cases studied, the proportion of life cycle after-sales profits vary depending on the value and profit margin of the initial sale.

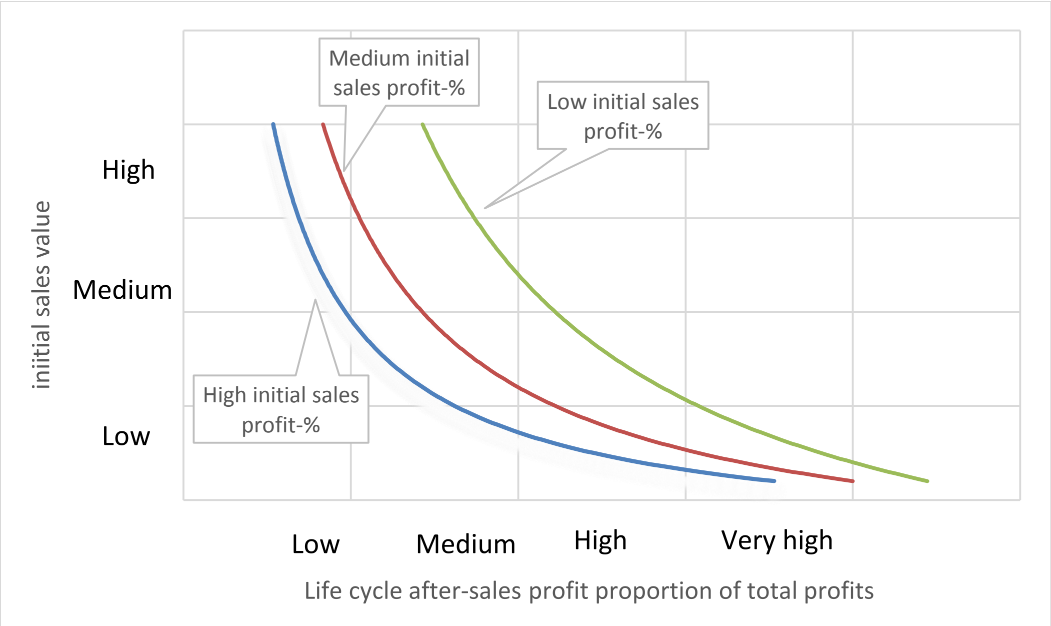


Figure 47: Waste to energy crane's NPV of after-sales compared to initial sales value.

For the steel and coker cases it is difficult to estimate how well the analysis gives the same results to similar cranes due to lack of available cases. Actually, there were three coker cases, but two of them were not included in the analysis due to their short history. However, the analysis was performed for these two cranes as well and in those the expected life cycle after-sales profits were significant as well. For the steel case crane, based on the branch manager's judgment, the used data should be rather similar with other such cranes. Therefore, also the results could be expected to be of the same fashion, if the analysis was performed for more of this type of cranes.

6.2 Analysis of the results

In the calculations both service and spare part after-sales profits are considered based on an assumption that, if the crane was not sold by Konecranes, then these profits would be lost. This could be the case for example, if a requirement for a lower crane sales price would be that the customer also makes a service contract for the crane from Konecranes, which they otherwise would not do. This is possible, but in practice it is difficult to know whether the customer would or would not make a service contract without the price cut of a crane. Konecranes does provide maintenance services for other than Konecranes cranes, so it is also possible to still get the service contract even if the crane was not sold by the company itself.

In most cases the after-sales spare part profits can be considered as lost profit (in addition to the lost initial sales profits), if the crane is not sold. Konecranes does provide spare parts for other manufacturers' cranes too, but this is relatively limited at the moment.

According to the analyses, the proportion from spare parts of the after-sales profits was between 23-59% (average 46%). Average percentages for crane types are presented in table 19. Out of the net present value of after-sales profits this percentage of profits can be considered to be lost, if the crane was not sold. In order for the crane price reduction to be profitable, the reduction should be less than this spare part proportion of the net present value of after-sales profits.

Table 19: Average percentage of after-sales NPV from spare parts.

Crane type	**Average percentage of after-sales NPV from spare parts**
Waste to energy	50%
Steel (only one case)	23%
Coker (only one case)	59%
All case cranes	**46%**

Table 20: Three possible scenarios with imaginary values. Life cycle after-sales profits calculated with 37.5% of total life cycle profits.

Scenario	1	2	3	4
Minimum sales price:	1000	950	900	855
Initial sales profit:	250	200	150	105
Future profits:	Not considered	Considered	Considered	Considered
Customer:	Price too high, no deal	Price ok, deal	Price ok, crane deal + service contract	Price ok, crane deal + service contract
Result:	No after-sales spare part profits	After-sales profits gained 60k€	After-sales profits gained 60k€ (spare parts) + 90k€ (services)	After-sales profits gained 60k€ (spare parts) + 90k€ (services)
TOTAL	0	260k€	300k€	255k€

In table 20, four possible scenarios are presented. The data in the scenarios is imaginary, but they provide an insight into how the results of the analysis could be used in pricing. The life cycle after-sales profit is calculated from scenario 1 profit with an assumption that 37,5% of overall profits come from after-sales. Also, an assumption is made that 40% of these after-sales profits are from spare parts and 60% are from services.

Scenario 1 is when the customer considers the offered price too high and orders the crane from somewhere else. In this scenario, the seller does not consider the possible future profits enabled by the crane sale, and will not lower the price. In this scenario also the after-sales profits of spare parts are lost. There is no profit made from the deal.

In scenario 2, the spare part after-sales profits are considered already in the offering phase. In this scenario the price can be further adjusted by the maximum of the net present value of the spare part after-sales. As long as the price adjustment is less than the net present value of otherwise lost profits, it can be seen as profitable, since these profits can be assumed to be gained over the life cycle of the crane, if there is a deal.

In scenario 3, it is known that the customer was not going to make a service contract with Konecranes originally. They are given a lower price sales offer with the condition of service agreement with Konecranes. In this case the price adjustment is profitable, if the net present value of profits exceeds a) the minimum profit requirement of scenario 1, and b) the total net present value of profits in scenario 2, if the customer would be willing to agree to the scenario 2 terms.

In scenario 4 it is also known that the customer was not going to make a service contract with Konecranes originally. If the customer would be ready to make the deal with the scenario 2 terms, then the scenario 4 would not be the best choice, even though compared to scenario 1 the deal would be profitable. So this scenario would be better than no deal at all, but not the best possible deal.

As already mentioned before, it is difficult to know at the time of sales about the customer’s true willingness to make a service contract. If it was realized by the customer that this could lead to price cuts, all customers would quickly claim that they are not considering making a service contract. Also, when considering the spare part profits, it should be noticed that not having a service contract may have a negative effect on the spare part profits as well, since some of the spare parts could be ordered from other sources.

On a profit-volume graph (see chapter 2.7.2) the expected shift would show as a negative for ICS business, if prices were cut without decreasing costs as well or increasing the number of sales significantly. However, since these sales enable more sales in different business units in the form of after-sales the overall result in the company would be increasing profits, as long as the price decreases are less than the net present value of estimated life cycle after-sales.

Figures 48 and 49 present the expected results on profit-volume graphs. Figure 48 presents the expected result on ICS profit-volume graph and figure 49 the expected results in other parts of the company. In ICS the price decreases could be expected to increase the number of cranes sold, as more projects would be won. However, this increase in sales quantity would not likely be enough to cover the lost profit from price drops, so profit could be expected to drop from P1 to P2 for ICS. This is of course negative from the ICS point of view, but as presented in table 20 scenarios, it can be profitable for the company overall. In other parts of the company the extra units sold create after-sales profits in the future. If the NPV of after-sales increases the profits so that (P4-P3) > (P1-P2), the ICS price adjustments have in fact been profitable. It should be noted that the analysis has been made based on the expectation that there is currently excess capacity and the fixed costs do not change, if more units are sold. If there is a change in fixed costs as well due to increased number of projects, then also this increase in fixed costs should be covered by the after-sales, for the price adjustments to be profitable.

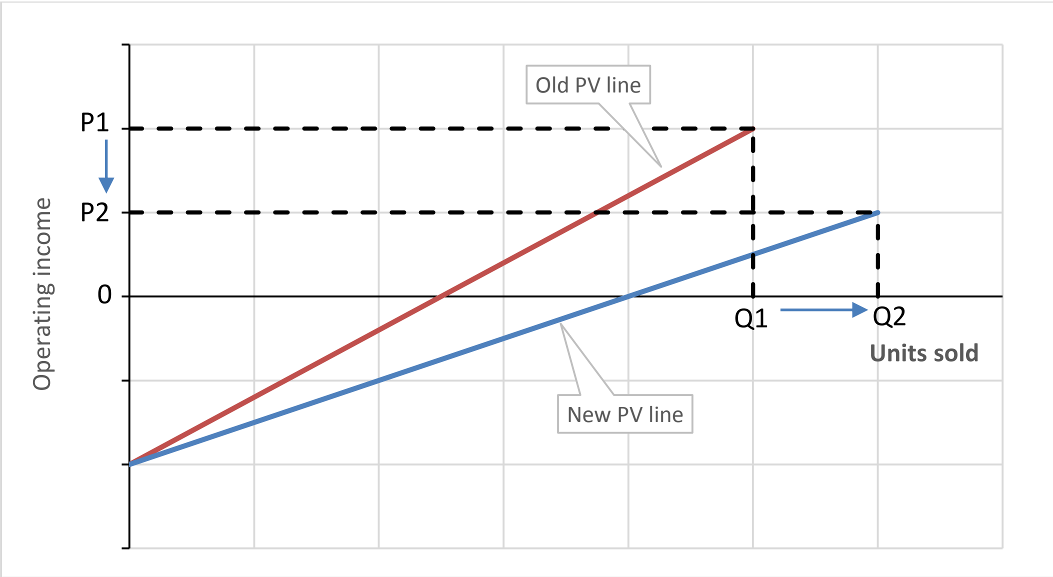


Figure 48: Illustration of results in profit-volume (PV) graph for ICS, if prices decreased.

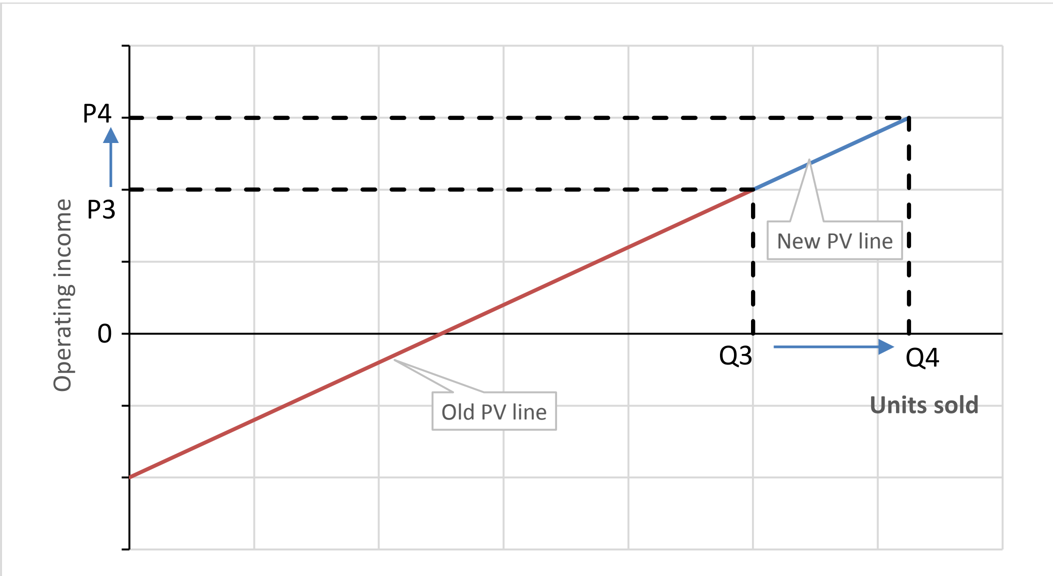


Figure 49: Illustration of results in profit-volume (PV) graph for after-sales, if more units sold by ICS. The blue "new PV line" represents the theoretical present value of the future after-sales for the cranes.

6.3 Conclusions and further research

The research questions set in the introduction part of the thesis have been provided with answers by analyzing case studies with the created life cycle profit model.

Spare part and service after-sales profits were analyzed and estimated over 20 years' time starting from the order year.

The results of the life cycle after-sales profit analysis can be considered to be conservative. Also, as the method used case studies, it cannot be clearly identified how well the chosen case studies represent their own segment's normal. Therefore the results provide only some clarification to the significance of after-sales to a crane's overall profitability.

In the studied segments the after-sales profits were found to be significant when compared to the initial sales profits. Considering the after-sales profits already in the offering phase might make the difference between winning or losing a profitable deal. The importance of after-sales profits in the overall life cycle profitability would seem to depend on 1. type of crane (segment) 2. value of crane 3. possibility to have a service contract.

Based on the analyses, the type of crane in question largely determines the life cycle after-sales profit making capability of the crane. More valuable cranes within the same segment tend to be less dependent on the after-sales profits. This does not mean that the life cycle after-sales profits would necessarily be insignificant, but that they are proportionally less important than the initial equipment sales profit. Possibility to have a service contract plays also a role in the life cycle after-sales profit making capability. In the case analyses the direct after-sales profits from service contract was between 12% and 53%, but the indirect effect on, for example, spare part sales could not be determined in this work.

There is plenty of room for future research. As already mentioned above, the data available for this thesis was limited to five cranes, so it is not clear how well the results from chosen case studies represent their own segment's normal. Larger scale investigations should be conducted to gain confirmation on the results.

In this thesis work the chosen types of cranes were expected to be more after-sales consuming due to their high usage. There are also a large number of different kinds of cranes sold for which after-sales are not expected to be that significant. Future studies should aim to clearly identify all the important after-sales intensive segments. In addition to the studied maintenance service and spare part after-sales profits, also the possible profits from modernization at the end of crane's life cycle should be included. The cranes often operate in facilities that operate for longer than the crane's own service life. Modernization is an important business and the profits are likely to be significant. One final suggestion for future research would be to investigate and quantify the effects of having a maintenance contract on the volume of spare part after-sales and on the possibility of a future modernization deal.

REFERENCES

Barringer, H. P., Weber, D. P. 1996. Life Cycle Cost Tutorial. [WWW-document]. [retrieved July 08, 2014]. Available: http://www.barringer1.com/pdf/lcctutorial.pdf

Boussabaine, H. A., Kirkham, R. J. 2004. Whole life-cycle costing: risk and risk responses. Blackwell Publishing, Oxford. 242 p.

BS 5760-23. 1998. Reliability of systems, equipment and components – Part 23: Guide to life cycle costing.

Burch, J. G. 1994. Cost and management accounting: a modern approach. Saint Paul, West Publishing company. 1212 p.

Fabrycky, W. J., Blanchard, B. S. 1991. Life-Cycle Cost and Economic Analysis. Prentice Hall, Englewood Cliffs, NJ. 384 p.

Government of India. 2014. Office of Economic adviser. [retrieved October 28, 2014]. Available: http://www.eaindustry.nic.in/home.asp

Hagberg, L., Hautanen, S., Henriksson, T., Laine, H. S., Löppönen, P., Riikonen, E. 1996. Käynnissäpidon johtaminen ja talous. Loviisa, Scandinavian Center for Maintenance management Finland ry. 224 p.

Horngren, C. T., Datar, S. M., Foster, G., Rajan, M., Ittner, C. 2009. Cost Accounting: A Managerial Emphasis. 13. p. Upper Saddle River NJ, Pearson Prentice Hall. 896 p.

India Times. 2014. Government sets up a panel to devise new Producer Price Index to replace Wholesales Price Index. [online article]. [retrieved November 24, 2014]. Available: http://articles.economictimes.indiatimes.com/2014-09-01/news/53441864_1_ppi-wpi-revision-average-change

Järvenpää, M., Partanen, V., Tuomela, T-S. 2005. Moderni taloushallinto – Haasteet ja mahdollisuudet. 3.p. Helsinki, Edita Prima Oy. 359 p.

Järviö, J., Piispa, T., Parantainen, T., Åström, T. 2007. Kunnossapito. Kunnossapitoyhdistys ry, Hamina. 283 p.

Kawauchi, Y., Rausand, M. 1999. Life Cycle Cost (LCC) analysis in oil and chemical process industries. Research paper. 78 p.

Konecranes. 2014. Annual report 2013. [e-document]. [retrieved November 24, 2014]. From: http://annualreports.konecranes.com/2013/pdf/konecranes-2013-all.pdf

Konecranes b. 2014. Petrochemical Industry Cranes. [online article]. [retrieved December 22, 2014]. From: http://www.konecranes.com/petrochemical-industry-cranes

Konecranes Steel book. 2013. Smarter where it matters in steel. 73 p.

Korpi, E., Ala-Risku, T. 2008. Life cycle costing: a review of published case studies. Managerial Auditing Journal. Vol 23, no 3, p. 240-261.

Lappeenrannan teknillinen yliopisto. 2013. 4. Vikaantumisen stokastinen arviointi. Teaching material, 20 p.

Meier, H. Völker, O., Funke, B. 2010. Industrial Product-Service Systems (IPS2): Paradigm shift by mutually determined products and services. International Journal of Advanced Manufacturing Technology, Vol. 52. pp. 1175-1197.

Neilimo, K., Uusi-Rauva, E. 2010. Johdon laskentatoimi. 6.-10. p. Helsinki, Edita Publishing Oy. 366 p

OECD.StatExtracfts. 2014. Producer Price Indices by types of goods. [retrieved October 28, 2014]. Available: http://stats.oecd.org/index.aspx?queryid=26987#

Saaranen-Kauppanen, A., Puusniekka, A. 2006. 5.5 Tapaustutkimus. Menetelmäopetuksen tietovaranto. Tampere, Yhteiskuntatieteellinen tietoarkisto. Ref [17.12.2014] http://www.fsd.uta.fi/menetelmaopetus

Taipale, V. 1998. Osajärjestelmän vaikutus prosessijärjestelmän elinjaksotuottoon: LCP laskentamalli. Espoo, Valtion teknillinen tutkimuslaitos, VTT – Tiedotteita – Meddelanden – Research notes 1920. 52 p.

Tilastokeskus. 2014. Tuottajahintaindeksit 2005=100. [retrieved October 24, 2014]. Available: http://193.166.171.75/Dialog/varval.asp?ma=010_thi_tau_101&ti=Tuottajahintaindeksit+2005%3D100+%28TOL2008%29&path=../Database/StatFin/hin/thi/&lang=3&multilang=fi

Uusi-Rauva, E., Paranko, J. 1998. Kustannuslaskenta ja tuotekehityksen tarpeet. Tampere university of technology research paper.

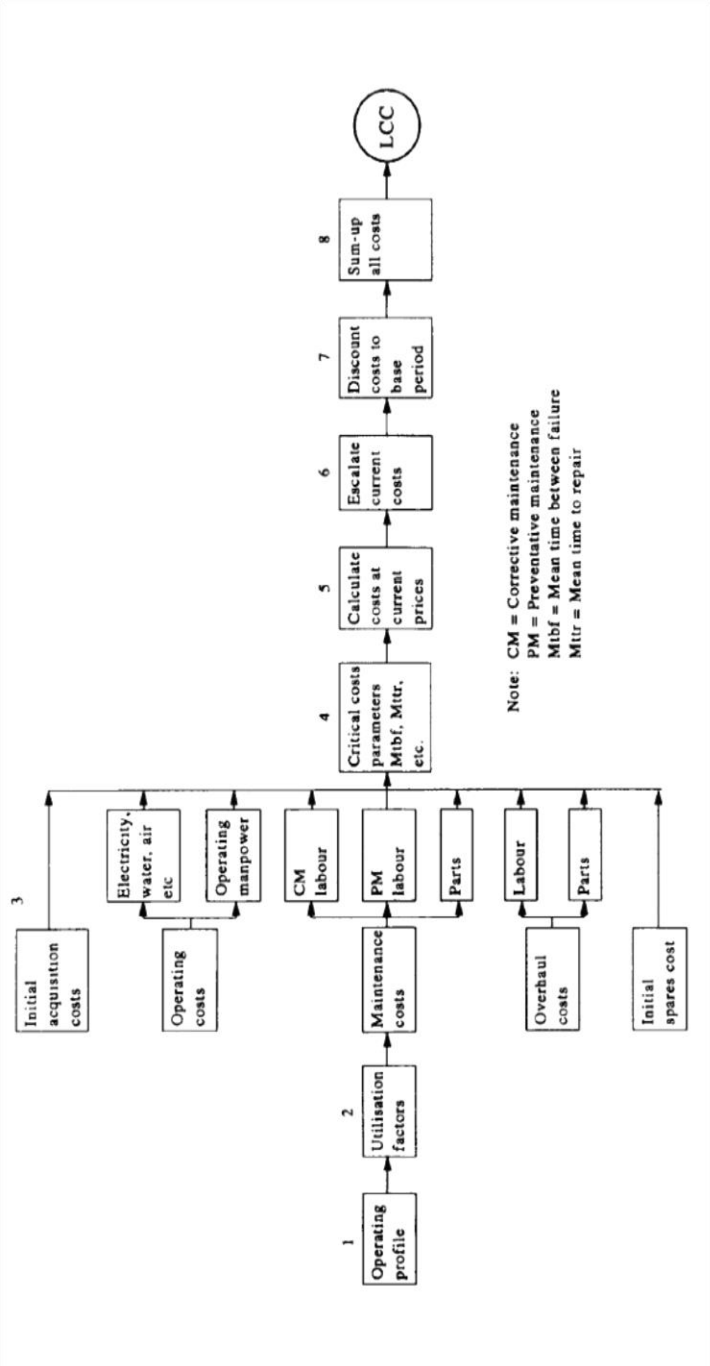
White, G., Ostwald, P. F. 1976. Life cycle costing. Management Accounting, January, pp. 39.

Woodward, D. G. 1997. Life cycle costing - theory, information acquisition and application. International Journal of Project Management. Vol 15, no 6, p. 335-344.

Wise, R., Baumgartner, P. 1999. Go downstream – The new profit imperative in manufacturing. Harward business review, Vol, 77. pp. 133-141.

APPENDICES

APPENDIX 1/2 : Kaufman's eight step approach for LCC formulation.



APPENDIX 2/2 : QUESTIONNAIRE

Instructions:

There are 7 multiple choice questions. Please choose one of the given options for each question and, if needed, you can add comments freely after the question.

About the used data in general:

1. How reliable is the used crane specific history data about the sold spare parts and services?
   a. Very reliable. All significant sales have been taken into account and no additional sales have been included.
   b. Reliable. Some differences to what has actually been sold are possible, however the used data is probably close enough.
   c. Unreliable. There probably are significant amount of sales not related to these cranes or a significant amount of sales have not been taken into account in the data.
   d. Very unreliable. The amount of sales is clearly off and not even close to what has actually been sold.

   Choice: ___

   Free comments to question 1:

2. The sales in history data are most probably:
   a. Above actuals. In monetary value there are probably more sales included in the data than the actual sales to these cranes.
   b. Below actuals. In monetary value there are probably less sales included in the data than the actual sales to these cranes.

   Choice: ___

   Free comments to question 2:

Used CMII-% estimates:

3. The used CMII-% estimates are:
   a. Accurate enough. No significant differences to the actual ones.
   b. Some changes would be needed (please type in the changes into the table below):

	Used CMII-% estimate	**A better CMII-% estimate**
SP21 (labour)		
SP22R (labour)		
SP22M (labour)		
SP23 (labour)		
SP27 (labour)		
Materials (”Spare parts”)		

Choice: **___**

Free comments to question 3:

4. In the calculations an assumption was made that all the materials have been ordered from KC spare part center. This way there is profit to both frontline and the part center.

   Is this assumption:

   a. Completely correct. There should be no exceptions to this.
   b. Correct enough. There may be some exceptions, but in monetary value they are not significant.
   c. Wrong. In monetary value a significant amount of the spare parts are ordered to front line from somewhere else than KC spare part centers.
   d. Completely wrong. In monetary value only a small proportion of the sold materials are ordered from KC spare part center.

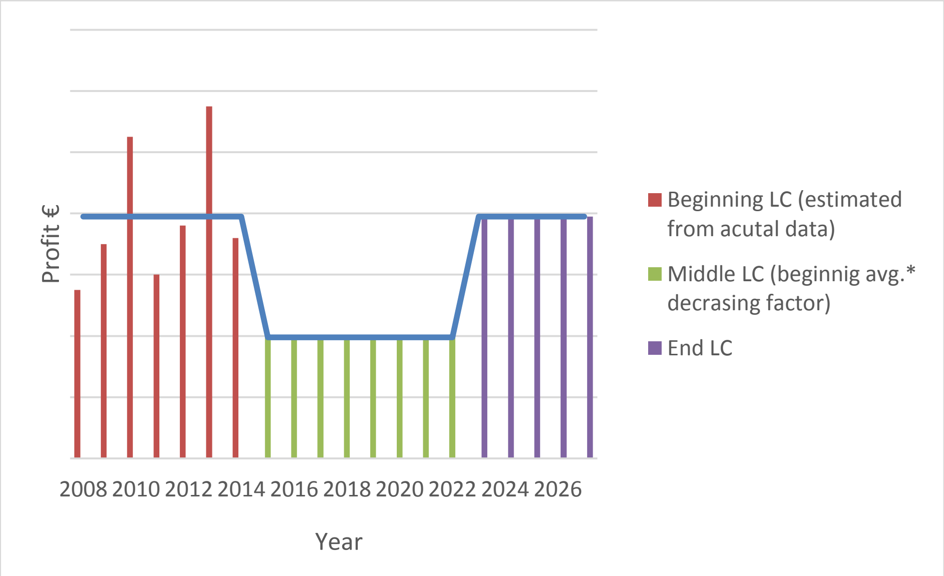
   Choice: **___**

   Free comments to question 4:

Future estimates:

Based on the bathtub curve (theory) an assumption was made that the need for repair, and therefore maintenance service and spare part sales, is lower in the middle period of the life cycle than in the beginning and end periods of the life cycle. A crane life cycle was estimated to be 20 years. (Beginning = history data, end = the last 5 years, middle = the time between those two.)

Illustrative picture:



The blue line is the average annual profit during each period. Red bars are from history data (beginning of life cycle), the grey bars are the estimated annual profits over middle period of life cycle, and yellow bars are the estimated annual profits over the last 5years of the life cycle. (The picture above is only an illustration)

5. In the calculations an estimation was made, that profits (and sales) are half of the beginning years' average annual profits (= 0,5 * average annual profits in history data) for all other than SP21 sales. SP21 profits are assumed to stay the same throughout the life cycle.

   Is the used "decreasing factor" 0,5:
   a. A good estimate.
   b. Too low. Estimates for future profits are probably too low with this factor.
   c. Too high. Estimates for future profits are probably too high with this factor.

      Choice: ___

      Free comments to question 5:

6. If you chose b or c to the previous question, which of the following would be best alternative factor:
   a. 0,25
   b. 0,75
   c. 0,90
   d. 1
   e. Other, please specify?

      Choice: ___

      Free comments to question 6:

Final question:

7. How well do you believe the collected history data represents other WTE/Steel cranes' (operating in a similar task) spare part and maintenance needs in general?
   a. Well. Almost similar amount of labour and spare parts should be needed no matter where the crane is located.
   b. Relatively well. There can be differences, but there are no special known reasons, that these cranes would have required exceptionally lots/little maintenance or spare parts.

c. Relatively badly. These cranes have had exceptionally lots of maintenance and/or spare part needs, which should not occur normally.
d. Badly. Usually this kind of cranes’ spare part and maintenance needs are significantly higher/lower.

Choice: ___

Free comments to question 7:

Thank you!