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Modelling of Finnish maintenance markets and its development

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TIIVISTELMÄ

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Tämä tutkimus on toteutettu Promaint ry:lle ja tutkimuksen ensisijaisena tavoitteena oli mallintaa ja tarkastella suomalaisen kunnossapitomarkkinan kehitystä ja kokoa. Lisäksi tutkimuksessa tarkasteltiin trendejä ja muutoksia kunnossapidossa ja niiden vaikutusta kunnossapitomarkkinan kokoon. Viimeisin tutkimus Suomen teollisuuden ja infrastruktuurin kunnossapidon määriin on tehty 2000-luvun alkupuolella ja tässä tutkimuksessa tavoitteena oli päivittää aiemman tutkimuksen tuloksia ja laajentaa tutkimusta kunnossapitoviennin parissa.

Tutkimuksessa laadittiin malli, jota voidaan tulevaisuudessa jatkuvasti päivittää, kotimaisen teollisuuskunnossapidon, infrastruktuurinkunnossapidon ja kunnossapitopalveluiden viennin määrien ja kehityksen selvittämiseksi. Mallinnuksen lisäksi toteutettiin kyselytutkimus, jonka avulla tarkasteltiin kunnossapidon kehitystä, teollisuuskunnossapidon työntekijöiden määriä ja muutoksia kunnossapitomenetelmien käytössä. Lisäksi tutkimuksessa ennustettiin kunnossapitomarkkinoiden kehitystä lähivuosina.

Mallinnuksen avulla saatiin tulokseksi Suomen kotimaisen teollisuuskunnossapidon määräksi noin 4,1 miljardia euroa vuonna 2016 ja ennusteeksi teollisuuskunnossapidon määrän kasvuksi tulevaisuudessa noin kaksi prosenttia vuosittain. Infrastruktuurin ja rakennusten kunnossapitomarkkinan koko oli noin 9,7 miljardia euroa ja rakennuskannan kunnossapidon määrä kasvanee tulevaisuudessa vuosittain noin kolmella prosentilla. Lisäksi suomalaisten yritysten kunnossapitoviennin määrä oli noin 12,3 miljardia euroa ja kunnossapitoviennin voidaan odottaa kasvavan tulevaisuudessa vajaat 300 miljoonaa euroa vuosittain.

ABSTRACT

Author: Tuomas Repo **Subject:** Modelling of Finnish maintenance markets and its development	
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Master's Thesis. Lappeenranta University of Technology, Industrial Engineering and Management. 69 pages, 21 figures, 8 tables, 3 equations and 5 appendixes Supervisor(s): Professor Timo Kärri University lecturer Tiina Sinkkonen	
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This thesis was written for Promaint ry and the primary objective of this study was to model and analyse size and development of Finnish maintenance markets. Additionally, trends and changes in maintenance and effects of these changes to maintenance markets were analysed in this study. Latest estimates in size of maintenance expenses in Finnish industry and infrastructure have been done in early 2000's and goal of this study was to update these estimates and to expand estimates among maintenance export sales.

As a result of this study an updatable model on maintenance amounts and future trends of domestic Finnish industrial maintenance market, Finnish infrastructural maintenance market and Finnish maintenance export service market was made. Additionally, a questionnaire was done in which questions on development of maintenance, amounts of industrial primary maintenance workers and changes in industrial maintenance methods were asked and these answers were analysed. Forecasts were made on possible changes during the next few years in all modelled markets.

Results from the model show, that domestic Finnish industrial maintenance market had size of about 4,1 Billion euros in 2016 and industrial maintenance amounts can be expected to grow by two percent annually. The amount of maintenance in infrastructure and building stock was about 9,7 Billion euros and the amount of maintenance in building stock can be expected to grow annually by three percent. The size of maintenance export market was about 12,3 Billion euros and can be expected to grow by just under 300 Million euros annually.

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Of course, this project has not been completed in a vacuum. So many thanks have to be given to my family and friends for both supporting me during my studies and for everything else. The years spent studying have truly been the best times of my life so far and would not have been the same without all of you!

Tuomas Repo

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1 INTRODUCTION

1.1 Background

Maintenance has often been seen only as a cost group for industrial companies. Even though, managing maintenance correctly is an important aspect to secure profitability of the company. This hidden importance has led to the research in some fields of maintenance being limited. (Hagberg et al., 1998, p.28; Järviö, 2007, p.16; Mikkonen et.al., 2009, p.25)

Maintenance is done by everyone, that have working capital or assets, that are needed to be upkept. Maintenance is done for industrial equipment, infrastructural assets and for private property to upkeep the working condition of these assets, but most often in scientific literature maintenance is talked in the framework of industrial maintenance, which includes everything from planning and management of maintenance actions to optimizing timing of maintenance actions, while sometimes maintenance is only seen as a tool to fix faults. (Järviö, 2007, p.8-9; Mikkonen et.al., 2009, p.25)

Through the prevalent nature of maintenance, it has become a notable part of economy. While maintenance costs are partly internal, there are notable sales in outsourcing of maintenance activities and spare parts sales. Maintenance services have also become important offerings for multiple product-oriented companies, which has distorted the line between a product sales and maintenance services. Latest widescale estimates on Finnish maintenance market would make it the fourth largest industry in Finland, if all primary maintenance personnel in different industries were counted to work in single industry of “maintenance”. (Kunnossapitoyhdistys, 2003; Vaittinen et.al. 2017)

Finnish maintenance society Promaint Ry, the Finnish branch of European Federation of National Maintenance Societies (EFNMS), has gathered market data for past 20 years to estimate the size of maintenance industry in Finland. Unfortunately, data gathering has become harder in recent years as industrial markets have become more competitive. This is the main reason for why more extensive research was needed and this study was conducted.

There are some earlier estimates on state of domestic Finnish maintenance markets, but these studies are quite old, and to name few there are studies by Torttila (1994), Kunnossapitoyhdistys (2003), Komonen (2005) and the most recently in Kunnossapidon Vuosikirja 2010 by Kunttu et.al. (2010). There is research done on state of maintenance in American companies by Blache (2009a; 2009b). There are also estimates made for EFNMS including French maintenance market (Pichot, 2017) and questionnaire on mainly Spanish maintenance market (Cuervo & Tormos; 2016). Development of maintenance market and related indicators in Austria have been analysed by Stuber and Dankl (2010). These estimates to other markets provide good background for modelling and comparison points for results of this study. Development of maintenance market can be analysed with comparisons to these studies and to general trends in scientific literature in maintenance.

1.2 Research problems and objectives

Primary objective of this study is to develop a model and an analysis, that provides estimate on the size and state of Finnish maintenance markets. This analysis will be done on both domestically of Finnish industry and infrastructure and on the maintenance exports of companies based in Finland. As a secondary objective of the study, trends in the development of maintenance markets will be researched and analysed in this study. The future development of markets is studied both by studying trends in literature and corporate world and by making estimates on changes up to year 2018 and these trends from modelled years are extended up to year 2020. Research objectives of this study can be divided into three research questions, which are:

1. *How can the domestic Finnish and export maintenance markets be modelled?*
2. *What are the results from these models?*
3. *What are the trends in maintenance market in recent years and in the future?*

The study is limited to Finnish market, as it is the primary interest of Promaint as there are organisations under EFNMS for different countries, which are responsible for research of maintenance in their own markets. Export market of course effectively includes vast parts of nondomestic industrial and infrastructural maintenance.

Modelling is done over the past four years to provide large enough basis for analysis. These four years should be long enough to find averages for maintenance markets. This development of four years should be a good base to be used as a background for predictions for maintenance markets. The model is built so it can be updated systematically in the future, so Promaint can publish up to date information in the future. Also, timeframe of four years is a good base to continue modelling in the future and to expand on this research later.

1.3 Research methodology

Theoretical background for this study is composed from simple explanation of maintenance and maintenance costs. After which development of maintenance markets are analysed, in this part also future of maintenance market is analysed trough scientific sources. Also, larger external and internal factors affecting different parts of market like maintenance backlog and different maintenance acquisition methods are analysed to achieve substantial understanding of different factors affecting the market and its development.

The primary research method used in this study is modelling. Modelling in this study refers to calculations and analysis on historical data sets and estimates on maintenance costs, which are used to calculate maintenance costs for different industries, different parts of infrastructure and maintenance exports. Predictions for changes in these maintenance markets are also made with assist from external predictions. Different parts of modelling are shown extensively in chapter 3 and model is composed from three different distinct parts, which are Industry and mining, Infrastructure and Exports. The earlier research on Finnish domestic maintenance market of Kunnossapitoyhdistys (2003) was mostly done on Industry and infrastructure and when compared to this earlier study the model on export market is new addition in this study.

Industry and Mining are modelled trough turnover statistics and maintenance cost industry averages on different industries. Infrastructure is modelled trough maintenance costs estimated in various sources and trough calculations for few parts of infrastructure. Lastly, export markets are modelled trough export maintenance sales for largest Finnish companies, list of 501 largest Finnish companies was gathered and this list was limited to more relevant companies through simple research on the primary offerings of these companies. At this point the list was comprised of 49 companies to be analysed further. Out of these companies some were subsidiaries of other companies in the list and for few companies had no reliable exports or maintenance turnover amounts available. At the end, accurate estimates were calculated for 24 companies.

To support modelling a questionnaire was used as a research method. The questionnaire was done to find indicators for industries and to find concrete answers to compare to the development trends found in literature. The questionnaire was send to a select group of answerers, which was composed of members of Promaint and representatives of member companies. The group was selected like this to ensure reliability of the answers, as all answerers actively work with maintenance or maintenance management in their respective industries. The questionnaire was send to 49 persons working with maintenance management, from these persons 10 answered to the questionnaire, which gives an answer rate of 20,4 percent.

1.4 Structure of study

In Figure 1 the structure of the study can be seen. There are 7 chapters in this study. In the first chapter of this study introduces subject, research objectives, research questions, methodology and structure of this study.

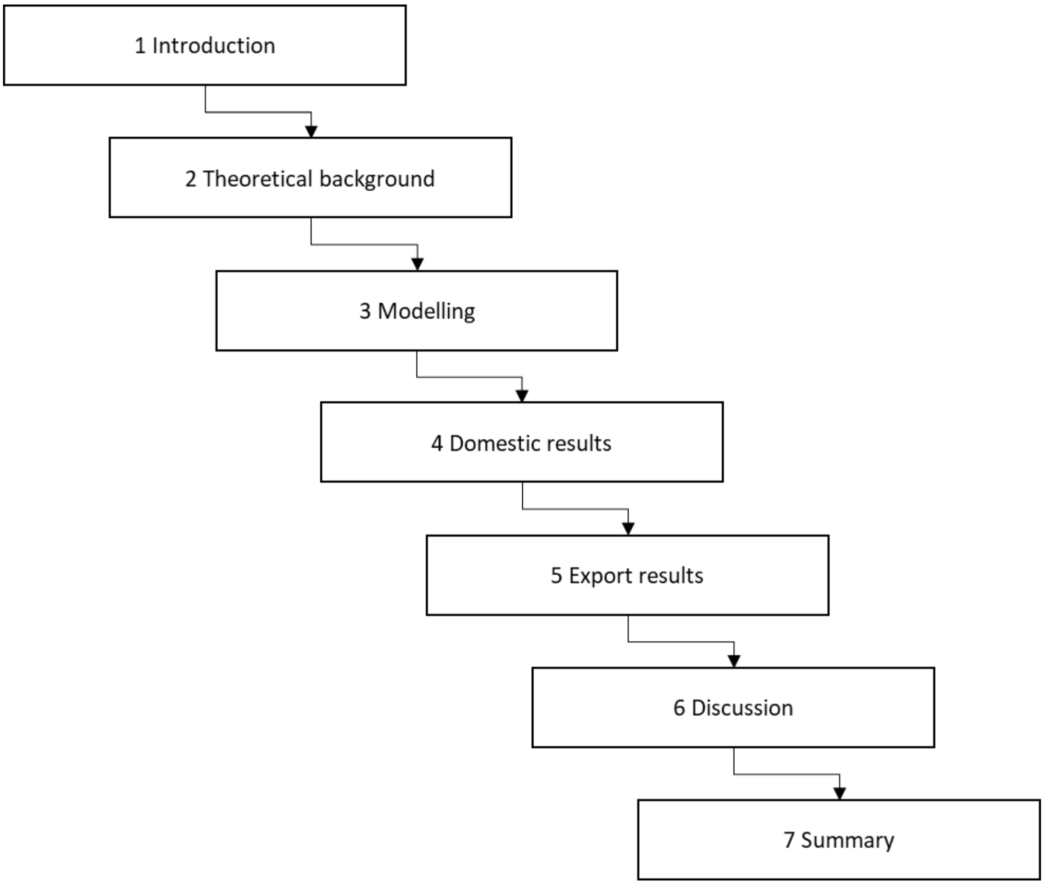

Figure 1 Structure of the study

In chapter 2 maintenance markets are analysed trough definition of maintenance and different subtypes of maintenance. After which history of development of maintenance markets are analysed. Then recent trends of maintenance outsourcing and servitization of product-oriented companies are explored. In the next part future trends of maintenance are analysed and in the last part of this chapter maintenance backlog is explained.

In the next chapter modelling done to find market size is explained. The model is comprised of 3 parts, which are domestic industry and mining maintenance market, infrastructure maintenance market and Maintenance exports. On top of this limited modelling in the future markets are done. The results from modelling can also be seen in Appendixes 2-5.

In chapter 4 domestic maintenance markets are analysed. Both results from industry and infrastructure are analysed in this chapter. Also, future maintenance market trends are analysed in this chapter and predictions for few future years are given. Answers from questionnaire is also analysed to see how changes in maintenance methods relate to earlier research.

In chapter 5 analysis on export market size is done. On top of this future expectations of modelled companies are analysed. Export market size and at the end of the study in chapters 6 and 7 conclusions of the study are gathered and shown. In the last chapter a brief summary about the study is written.

2 MAINTENANCE MARKETS

2.1 Definition of maintenance activities

There are many definitions for maintenance and in the standard SFS-EN 13306:2017 (p. 8) maintenance is defined as follows: “combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function.” From this definition maintenance must be seen to include much more than just the action of fixing faults in equipment as managerial and administrative factors are also included in the work of maintenance.

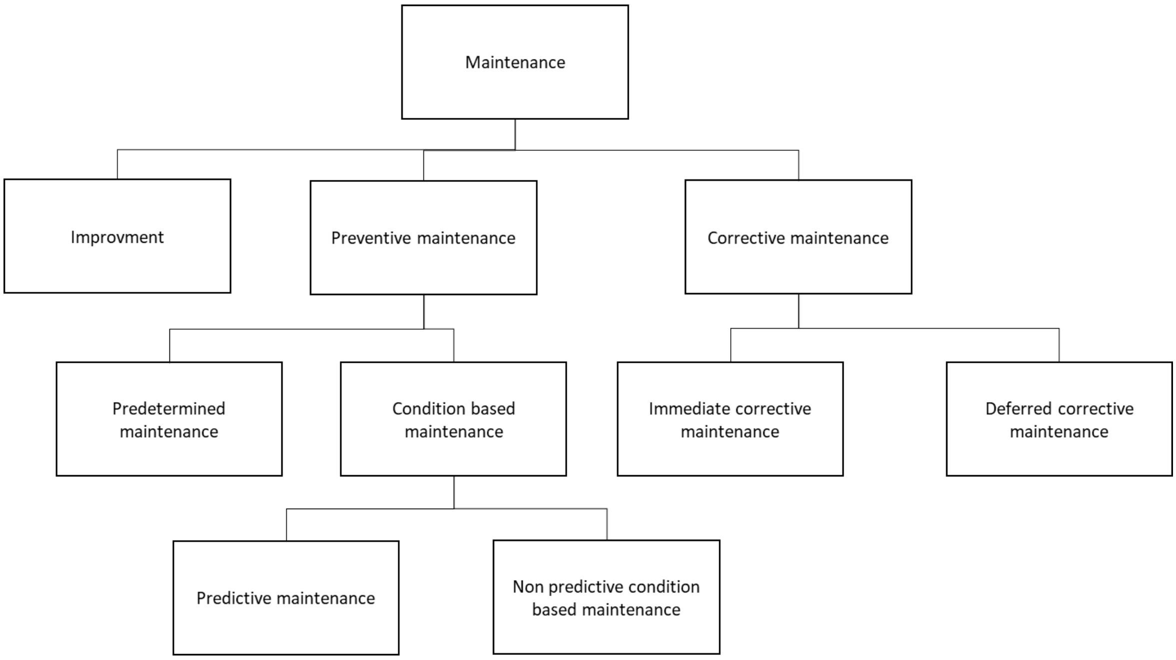

Figure 2 Maintenance types (SFS-EN 13306:2017, p.58)

Maintenance can be divided into multiple subtypes. These subtypes can be seen in Figure 2 and main subtypes are improvement, preventive maintenance and corrective maintenance. Improvement includes all actions to better reliability, maintainability or safety of an item. Preventive maintenance is maintenance carried out to stop degradation of these same aspects. Corrective maintenance includes all actions done to correct faults. (SFS-EN 13306:2017)

Preventive maintenance can be divided into predetermined maintenance and condition-based maintenance later of which can be divided to predictive and non-predictive condition-based maintenance (SFS-EN 13306:2017). It is important to be understand differences between different subtypes of maintenance, as some subtypes of maintenance will be more relevant in the future. Subtypes that are most commonly talked in research are corrective, preventive and predictive maintenance.

The most important subtypes can also be set on a staircase of development, which corresponds with the complexity and development of different maintenance subtypes (Mikkonen et. al., 2009, p. 22). Higher you get on the staircase the method is more complex and harder will the implementation of maintenance method be. This staircase is seen in Figure 3.

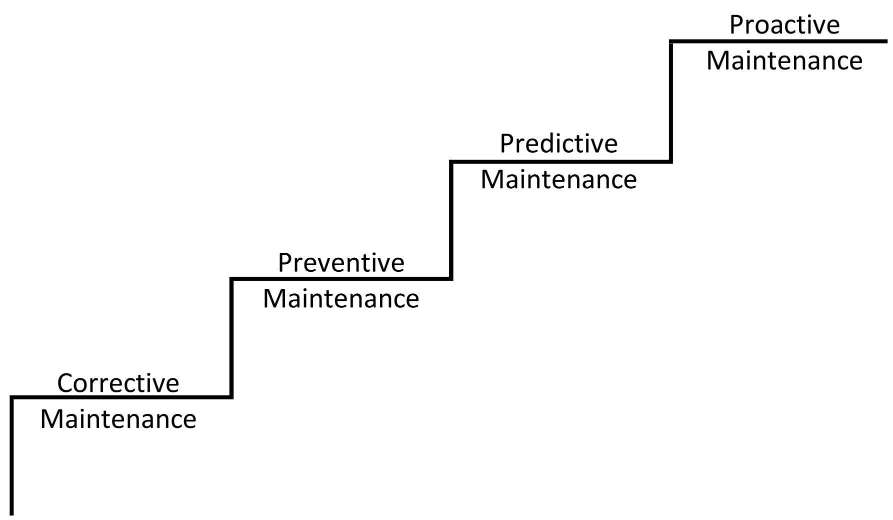

Figure 3 Staircase of maintenance methods (Mikkonen et. al., 2009, p. 22)

In this study maintenance is mainly processed through the economics of maintenance, so this subject is important to understand. If categorised as simplistically as possible maintenance costs can be divided into three distinct cost groups, which are direct, indirect and nonmaterial costs. Direct maintenance costs include costs like materials, spare parts, wages of maintenance personnel, storage costs and outsourced services. These costs are easiest costs to calculate and allocate to maintenance. Indirect costs are harder to allocate, and they don’t directly come from maintenance. These costs include costs like poor quality, lost production, and large storage costs. Nonmaterial costs are also indirect cost, but they have direct effects on the company. These costs include things like safety, motivation problems and loss of brand value or customer good will. (Järviö, 2003, p. 120-121).

Alternatively, Sinkkonen et.al. (2013) have provided more complex model that can be used for cooperative management of maintenance network. In this model there are eight distinct cost categories which are operating costs, machines and tools, spare parts, logistics, quality, subcontracting, environment and other costs. This study shows that in reality maintenance costs are not simple to define or even defined similarly between companies in the same network. So, generally can be said that maintenance costs and cost calculations vary on company and industry basis.

In this study most often when maintenance costs are discussed, they are seen in a frame of direct maintenance costs, or to include only spare parts, wages and subcontracting, as they are usually the only maintenance costs that are calculated. Also, indirect costs, like lost production, are not usually included in the maintenance cost indicators used in this study.

In Standard PSK 7201:2010 there are indicators defined for maintenance management. There are two business profitability and effectiveness indicators, that are relevant to this study, as they are used to indicate direct maintenance costs. These two indicators are M514.1 maintenance contribution to business and M514.2 maintenance contribution to machinery. M514.1 is defined as maintenance costs divided by turnover. While M514.2 is defined as maintenance costs divided by value of production machinery.

These two indicators are common indicators used to compare maintenance costs in industries and infrastructure. In infrastructure indicator M514.2 is used usually as there are no clear turnover for example in the road infrastructure. In industries and in the study primarily used indicator is M514.1 as estimating maintenance costs over turnover is easier as value of machinery for companies is not public information. (PSK 7201:2010)

2.2 Development of maintenance markets

The historical development of the maintenance can be divided to three distinct realised generations and a coming or current fourth generation. These generations can be defined trough dominant types of maintenance and by expectations and views on maintenance. (Moubray, 1997, p.1-4; Järviö 2003, p.11-15; Dunn 2003)

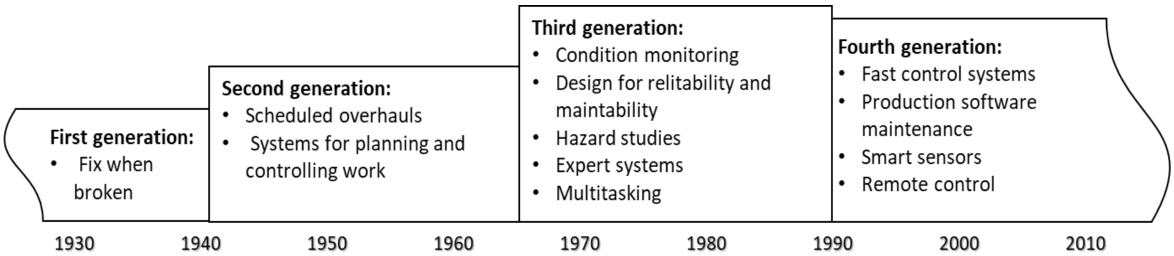

Figure 4 Generations of maintenance (Adapted from Moubray 1997 p.3 & Järviö 2003 p.4)

In the Figure 4 different generations and defining factors of them are summarised. The first generation is considered as the time from industrial revolution up to the Second World War. The generation was defined by equipment being not very mechanised and machinery was simple and over-designed. This made maintenance easy and made equipment less likely to break. During this generation the dominant maintenance type was reactive maintenance. (Moubray 1997 p.2)

The transmission to second generation started to form during the Second World War as industrial equipment became more mechanised. Mechanisation was caused by industrial output needing to grow to satisfy the war effort while supply of available manpower dropped. Second generation introduced scheduled overhauls and systematic planning to maintenance, which introduced predetermined maintenance as a maintenance method. Because of these new methods managers now had expectations of lower maintenance costs and longer equipment life. (Moubray 1997 p. 2)

Third generation of maintenance is estimated to have started at 1970’s. Third generation has introduced condition monitoring, maintenance method of condition-based maintenance and design for maintainability and reliability. Which has moved expectations to even higher equipment availability and greater cost efficiency. Also, environmental factors and safety factors have become important during this generation compared to earlier generations. (Moubray 1997 p. 2-3)

As Moubray (1997) has defined the generations in early 1990’s and his definition lacks the most recent developments. Dunn (2003) has studied expectations and methods for what he calls the upcoming fourth generation**.** He predicts that fourth generation will focus on failure elimination rather than only predicting or prevention of failures.

Järviö (2003) has also given predictions on the fourth generation of maintenance, but, in his opinion fourth generation has already started in 1990’s at the breakthrough of ICT-technologies. He predicts that new improvements in sensor technology and new technologies, like Artificial Intelligence, being implemented to maintenance, which allows maturation of predictive maintenance. Järviö (2003) also expects the trend of growing complexity of equipment to continue, which will lead to still higher production and maintenance costs, but he expects the production costs per unit lowering as production quantity will grow faster than maintenance costs.

Related to development of maintenance along the years there has been ideas presented on how probability of failure relates to the life cycle of equipment. These different failure patterns are shown in Figure 5. When failure probability grows productivity of equipment lowers and both direct and indirect maintenance costs can be expected to be higher.

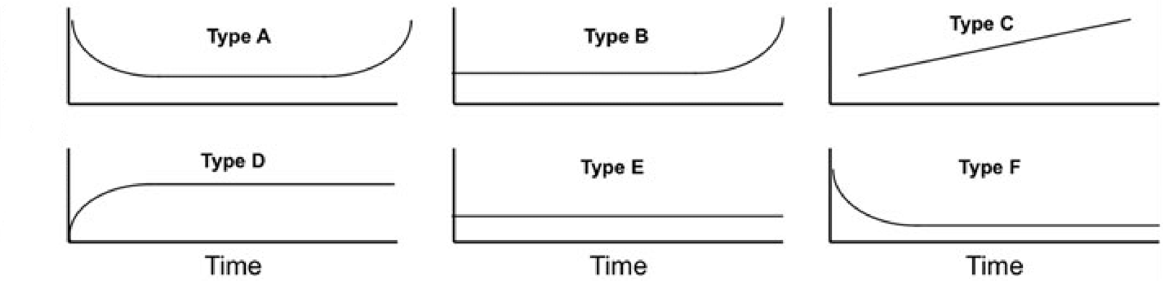

Figure 5 Failure probability curves (Nowlan & Heap, 1978)

Traditional view on failure probabilities during first generation of maintenance was pattern B, where production equipment had production life after which came wear-out zone where probability of failure and maintenance costs grew drastically. During the second generation of maintenance pattern A was coined, which is based on the idea of failures happening more in “Bathtub curve.” This means that on top of late in equipment life there are infant failures, which cause more failures when equipment is first taken into use. (Moubray, 1997, p.12)

Other four patterns were coined during third generation and pattern C shows constant small growth of probability. Pattern D shows low initial failure rate after which failure probability fast stabilizes to stable probability of failure. Pattern E shows no correlation between life cycle and probability of failure and pattern F shows bathtub curve without the end of life problems. (Moubray, 1997, p.13)

There is no universal pattern, that can be used for all equipment to predict failure probabilities. Ground-breaking study with civil aircrafts on this field was done by Nowlan and Heap (1978). In this study it was found that most assets had failure probability patterns following patterns F and E and only about 11 percent followed A, B or C, that have higher failure rates in later parts of life cycle.

Aircraft maintenance cannot be directly translated to other industries and generally both higher probability of failures and maintenance costs can be expected for equipment in late parts of equipment life-cycle (Moubray, 1997, p.13). On the other hand, infant failures are also commonly presented as a problem, but direct maintenance costs from these should not be as large as costs are mostly indirect loss of revenue instead of larger direct maintenance investments.

During the most recent generations as equipment has become more and more specialised outsourcing maintenance has become a hot topic among researchers and companies as maintaining more complex equipment will need specialised knowledge. (Torttila, 1994, p. 70; Deierlein, 1998). One of the reasons for moving towards outsourcing is the idea of concentrating on company's core competences (Prahalad & Hamel, 1990). Maintenance can easily be not seen as a core inhouse activity for company and thus be outsourced (Bernoli et al, 2004).

Service industry have grown to relevance in the past decades and many specialised companies offer maintenance as a service to their customers as their main offering. Meanwhile in recent years as growing competition from developing countries, need for higher quality products and price competition has cut into profits of traditional product-oriented companies. Some of these product-oriented companies have increasingly started to turn towards offering customers services with their products, or servitization of their offering, as a solution to these issues. (Bikfalvi et al. 2012; Vaittinen et.al. 2017)

Servitization was coined by Vandermerwe and Rada (1988) and servitization can be defined as a combining intangible services with tangible products into a combined product-service offering. Vandermerwe and Rada (1988) argues that whole service-product differentiation is outdated, and most offerings are bundles of both services and products. Servitization is also known as product-service systems or other conceptualisations like service growth strategy, hybrid offerings or transition from products to services. (Colen & Lambrecht 2013; Kowalkowski et al., 2016)

Goffin (1999) argues that services and product support are important to product companies as they are a major source of revenue and improve customer satisfaction, which can improve the chances for success of new products. While Oliva & Kallenberg (2003) provide three different reasons for manufacturing companies to provide product related services. First of which is services having higher margins than products. Second reason being support services being a precondition for sales of more complex products. Third reason being product-service offering being much harder to imitate than pure product offering, which gives company a competitive edge over its competition.

Service industry has been the fastest growing industry in the past decades and service production has been the largest part of production ever since 1960 in western Europe. Many specialised companies, that offer maintenance as a service to their customers as their main offering, have grown during recent decades. Service industry has also internationalised extremely fast as exports of services has become freer and easier through international treaties and development in technologies has removed limitations from service exporting. (Mankinen, et. al., 2001, p.1-2; Schön, 2013, p. 450)

While limitations have been removed Winstead and Patterson (1998) argue, that service export growth has been relatively slow compared to amount of removed limitations. According to them this slow growth can be explained by general lack of resources, expectations for large cultural differences and limited knowledge of export business in companies.

Related to outsourcing and servitization Rekola and Haapio (2009 p. 28) present six different maintenance acquisition methods can be divided to for following alternatives:

- Internal maintenance departments
- Internal maintenance departments with support from original equipment manufacturer (OEM)
- Outsourcing directly to OEM
- Outsourcing directly to OEM dependent
- Outsourcing to several service providers
- Outsourcing to single service provider

Maintenance markets have internationalised fast and according to Grönroos (1999) there are five major service export strategies which are not mutually exclusive. These strategies are direct export, systems export, direct entry, indirect entry and electronic marketing. Direct export is moving resources and systems whenever required for completion of services directly from domestic market to abroad. This method is commonly used in maintenance. Systems export is joint export effort to abroad by two firms, which have offerings that complement each other.

Direct entry strategy means establishing a subsidiary company abroad, which operates in this foreign market. To limit risks, it might be better to buy-out a local service operator rather than starting from scratch. On the other hand, indirect entry means establishing operation abroad by francizing or licensing to local operator. This method limits the risk in exporting, but it is more often done in food-service industry where offerings are more well-established than in maintenance industry. Last service export method is electronic strategies, which means extending accessibility of offerings by electronical technology. This method is not used in maintenance, but it is used for example in online stores and TV shops. (Grönroos, 1999, p. 293-295) Of course, development of digital maintenance methods could make last electronic entry methods usable in the future.

2.3 Future trends of maintenance market

The expectation of Järviö (2003) of lower cost per produced unit has already realised in some parts as there is evidence of lowering maintenance costs as percentage of sales. Average maintenance costs have lowered in North American manufacturing, assembly and process industry companies from 5,9 percent to 4,4 percent between the years of 1991 and 2008 (Blache, 2009a). A study conducted in Finland with similar companies and in the same time frame has produces similar values for average maintenance costs as percentage of sales of around 5 percent (Kunttu et al, 2010).

Maintenance costs most likely will continue to lower per produced unit as maintenance methods continue to develop. Most promising of these future methods is predictive maintenance, which is largely widely expected to be more and more important form of maintenance in future as 20 percent of companies see predictability as the most important factors in future of maintenance (Blache, 2009b). Still between 1991 and 2008 predictive maintenance hadn't grown noticeably and had stayed around 26 percent of maintenance and reactive has lowered to 12 percent, while preventative maintenance has grown to 62 percent of maintenance (Blache 2009a).

In the most recent studies expect, that the global predictive maintenance market will grow from 1,4 Billion dollars in 2016 to 4,9 Billion by 2021. Growth of predictive maintenance market will primarily come from Asia, Middle East, Africa and Latin America. (Business wire, 2017)

Predictive maintenance is only the most visible and easily predicted change in future. Internet of Things (IoT) is seen as a major factor to future of maintenance, as it will be one of the main factors in enabling growth of predictive maintenance market. (Collin & Saarelainen, 2016, p. 73) Growth of predictive maintenance needs maturation of IoT and digitalization of maintenance. The Internet of Things (IoT) can be defined as a new technology solution seen as a global network of devices, that can interact with each other (Lee & Lee 2015).

Internet of Things (IoT) is also coined through multiple other conceptualisations like Industrie 4.0, in German literature, and Industrial Internet of Things (IIoT), in American literature. Also, other definitions like Internet of Everything (IoE) and Industrial Internet are used often. All these definitions vary slightly, but they can be seen as synonyms, as they all talk about the same issue. (Collin & Saarelainen, 2016, p. 29-33)

Collin and Saarelainen (2016 p. 75) see also multiple different benefits of predictive maintenance compared to more traditional maintenance methods. These different benefits can be seen in Figure 6. These benefits include higher usability of equipment, better product quality, lower upkeep costs, fewer failures and cut in unnecessary maintenance done.

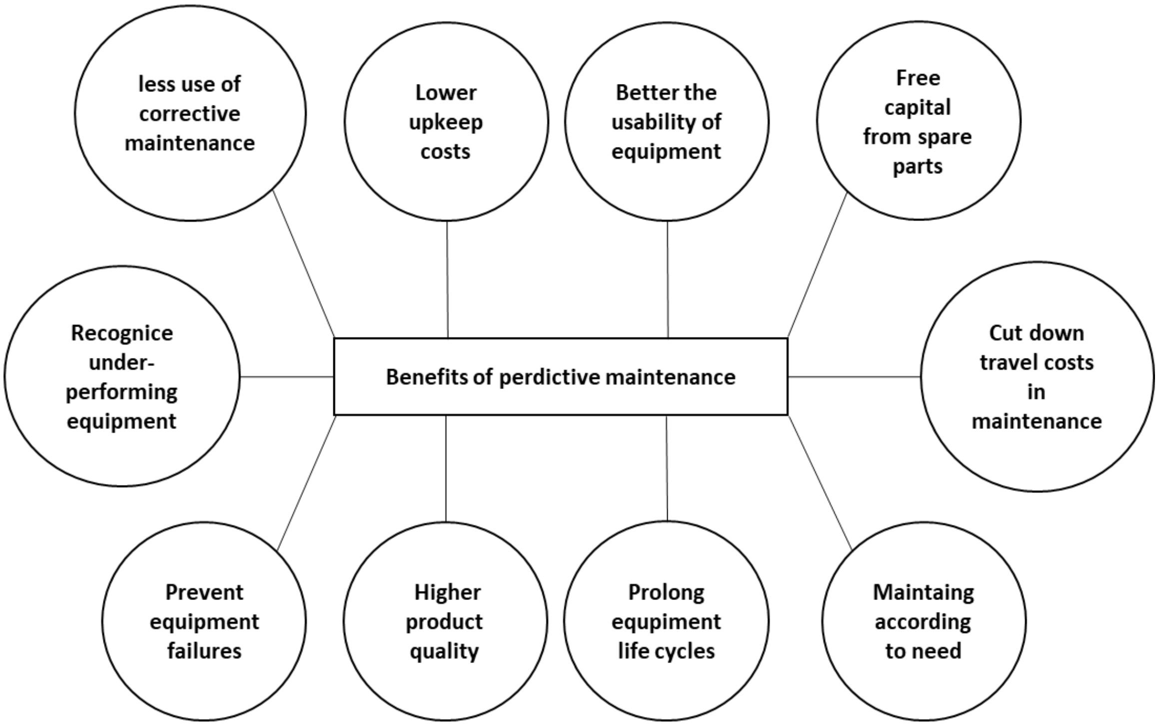

Figure 6 Benefits of predictive maintenance (Collin and Saarelainen, 2016, p.75)

On top of benefits there are some limitations on implementation of predictive maintenance. Data management and analytical skills of organisation are often cited as limiting factors for implementation of predictive maintenance. Large initial investment and long time needed to gather reliable information also limit the usability of predictive maintenance and data gathered might not be usable in other machines or environments. (Collin and Saarelainen, 2016, p. 74)

As an example, in 2016 Kone Oy has started offering predictive maintenance trough IoT to new lifts and escalators as the main maintenance model instead of calendar based preventive maintenance. Kone also predicts that older lifts will also be connected to IoT as new improved and more cost effective sensory technology is added to old equipment. (Garlo-Melkas, 2017, p. 20)

2.4 Maintenance backlog

Maintenance backlog is notable in size and it has direct impacts to markets. It is an important limiting factor in domestic maintenance markets. The size of maintenance deficit in infrastructure is estimated as 12 percent under sustainable levels, which can be calculated to cause 57 Billion euros of lost turnover over a period of 10 years. It is estimated that in year 2016 maintenance backlog was from 35 to 55 billion euros in Finnish infrastructure. This backlog is notable and similarly to the book value and maintenance in infrastructure, most of maintenance backlog is in the housing stock. Maintenance backlog is growing as current investments in maintenance in Finnish building stock and infrastructure are not sufficient. (Soimakallio et.al., 2017, p. 4-5)

Maintenance backlog was internationally defined for the first time in ERANET-backlog project and it was defined for road infrastructure as: “Maintenance backlog of the road infrastructure is the amount of unfulfilled demands at a given point of time in explicit reference to the predefined standards to be achieved. Maintenance backlog can be expressed in functional (non-monetary) or monetary terms and it refers to single components, sub-assets or to the whole road infrastructure asset of a given road network.” (Tiehallinto, 2009, p. 12)

So, from this definition maintenance backlog in this study is expanded to be defined as in non-monetary or monetary amount of maintenance demand unfilled to achieve certain level of predefined standards of maintenance for single components, sub-assets or to the whole infrastructure.

Maintenance backlog is often talked only in the concept of infrastructure, but effects of maintenance backlog also can be seen in industries. This maintenance backlog in industries is not as widely researched and there are no estimates how much this backlog effects the size of market. But high share of investments in repairing production equipment might indicate that in certain industries like, Manufacture of food products, Printing and reproduction of recorded media and Manufacture of basic metals, may have higher amounts of maintenance backlog and loss of production and lower maintenance amounts through it (Elinkeinoelämän keskusliitto EK, 2017).

Even though current maintenance investments aren’t enough to halt the growth of maintenance backlog. There are some ongoing attempts to stop the growth of the backlog. It is estimated that yearly investment of 100 million euros is needed to stop the growth of maintenance backlog in Finnish road infrastructure. Finnish government has allocated priority funding of 100 Million for year 2016, 300 Million for year 2017 and 200 Million for year 2018 to cut maintenance backlog of road infrastructure. (Soimakallio et.al., 2017, p.21-23)

2.5 Summary of maintenance markets

As seen earlier in this chapter, maintenance market is affected by multiple different factors. Even definition of the term “maintenance” includes multiple different offerings and actions in it. Maintenance includes both services and spare parts sales in it. Also, planning and managing maintenance work is included in the overall term. (SFS-EN 13306:2017) This definition of maintenance shows, that there are multiple different factors and offerings under maintenance, which makes estimating and comparing size of maintenance markets more complicated. This also means that maintenance market is composed of multiple different actions and actors.

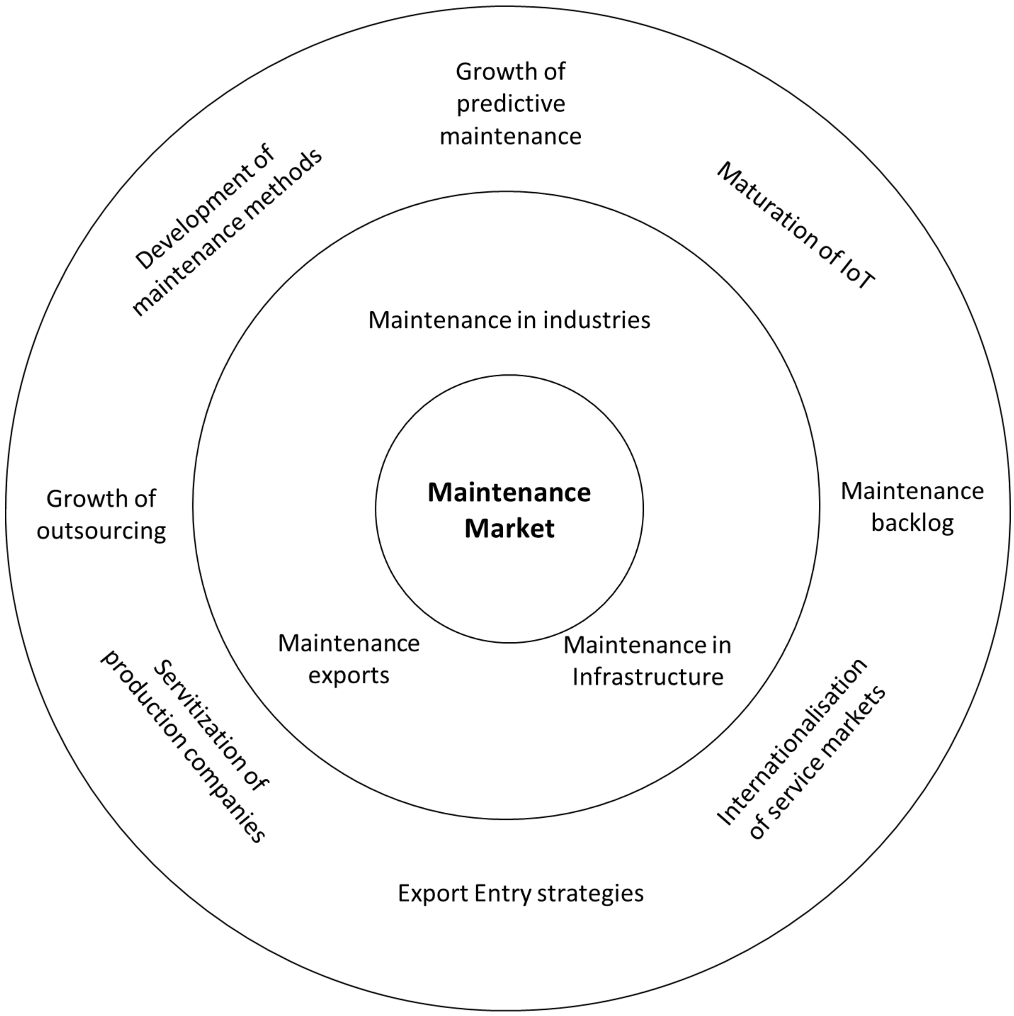

Figure 7 Factors effecting maintenance markets

In Figure 7 factors effecting maintenance market are gathered in a three-level framework. In the first level is the maintenance market, which is composed parts shown in the second level. In the third level is shown the major factors effecting maintenance markets. Development of manufacture techniques has caused the development of new maintenance methods as equipment has become more complex. The maintenance market has changed a lot in past decades and will continue to change as technologies continue developing and changing (Blache, 2009a; Mankinen, et. al., 2001, p.1-2). This development has caused changes in maintenance methods and it has contributed the growth of outsourcing in maintenance market as maintenance has become more complicated.

IoT will cause major disruptions in maintenance market. It is the major factor behind growth of predictive maintenance, as it is the clearest implementation of IoT (Saarelainen & Collin, 2016). IoT will cause the next large disruption in the maintenance market and might cause changes in market structure and maintenance amounts.

Trend of outsourcing and servitization of production companies have changed the market noticeably. Noticeable amounts of maintenance are currently outsourced. Outsourcing is often done to concentrate on company’s core competences and to find cost savings in maintenance. There are arguments given that there will be a wave of insourcing to regain control over company’s assets. Servitization of production companies have caused noticeable changes in maintenance service offerings and Original Equipment Manufacturers (OEM) are seen in two of the six major maintenance acquisition methods.

OEMs and traditional service companies are both major actors in Finnish maintenance export markets. This market has matured as service industries have internationalised lately. The major entry methods for maintenance companies are direct export, systems export, direct entry, indirect entry. Entry method chosen will affect the book value of maintenance exports, direct entry and export strategies grow the sales of companies, which can be seen directly in the model, while indirect entry with local partners does not show all sales of partner in company’s sales figures.

Maintenance backlog is a large limiting factor for maintenance market, as about 5,7 Billion of maintenance sales could be achieved annually for next 10 years from cutting maintenance backlog Finnish infrastructure. On top of this there are no extensive estimates for maintenance backlog in industries, but this maintenance backlog limits the size of industrial maintenance market.

3 MODELLING

3.1 Structure of modelling

Primary objective of this study is to make a model, that can be used in estimating different maintenance markets. Modelling can be divided in three distinct and different topics. These topics are Industry and Mining, Infrastructure and Export markets. Also, in the model there are limited models included for estimating future growth of each of the three.

All parts of the model span over four past available years. This is done to allow more extensive analysis of the market. Future of the markets will be analysed with data gathered from markets and predictions made by different organisations. In chapters 3.2 – 3.5 modelling logics for different parts of models is explained and accuracy of these parts are estimated.

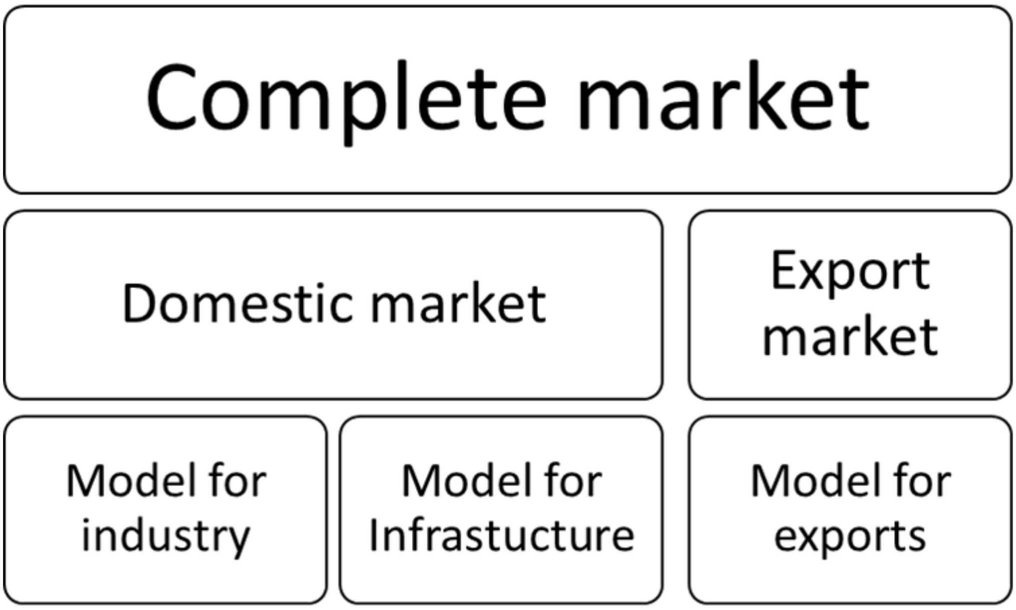

Figure 8 Structure of modelling

In Figure 8 structure of the market and relationships between different models are shown. Complete market is comprised of Domestic and Export markets, which are each analysed in respecting chapters, Chapter 4 and 5. Domestic market has been modelled with two distinct models, which are Model for industry and mining and Model for Infrastructure and Export markets are modelled trough a single model.

3.2 Maintenance in industry and mining

The part of model in industry and maintenance is done through estimating averages of maintenance cost indicators for an industry and comparing them to total annual turnover of an industry. Yearly turnover is taken from annual statistics of turnover for industry gathered by Statistics Finland (Statistics Finland, 2018).

Industries are categorised in Standard Industrial Classification TOL-2008, which is based on European NACE standards (Statistic Finland, 2008). In this part of the model two top level industries from TOL-2008 industries are included. These top-level industries are B Mining and Quarrying and C Manufacturing. Mining and quarrying will be estimated as a single industry, but manufacturing is divided in to 24 different industries for which maintenance costs are estimated trough different sources. These different industries are listed in Table 1.

The industries listed in Table 1 can also be grouped in industry groupings. These commonly used groupings are: 10-12 Food industry and manufacture of tobacco products, 13-15 Textile, clothing and leather industry 16-17 Forest industry, 19-22 Production of chemicals, rubber and plastics and a grouping of 24-30_33 Metal industry, which can be subdivided to 26-27 Electronics and the Electrotechnical Industry and 29-30 Manufacture of Vehicles. Also, industries of 24-30 are often grouped into a group of Technology industries or Machine shop industries.

Table 1 TOL2008 Industries (Statistics Finland, 2008)

B Mining and quarrying
C Manufacturing
10 Manufacture of food products
11 Manufacture of beverages
12 Manufacture of tobacco products
13 Manufacture of textiles
14 Manufacture of wearing apparel
15 Manufacture of leather and related products
16 Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
17 Manufacture of paper and paper products
18 Printing and reproduction of recorded media
19 Manufacture of coke and refined petroleum products
20 Manufacture of chemicals and chemical products
21 Manufacture of basic pharmaceutical products and pharmaceutical preparations
22 Manufacture of rubber and plastic products
23 Manufacture of other non-metallic mineral products
24 Manufacture of basic metals
25 Manufacture of fabricated metal products, except machinery and equipment
26 Manufacture of computer, electronic and optical products
27 Manufacture of electrical equipment
28 Manufacture of machinery and equipment.
29 Manufacture of motor vehicles, trailers and semi-trailers
30 Manufacture of other transport equipment
31 Manufacture of furniture
32 Other manufacturing
33 Repair and installation of machinery and equipment

There are some issues in this limitation to pure industries. Firstly group 33 is not like the other industries in the model, as it is not production industry, but purely a service industry. It can't be estimated in the same way as other industries and so can't be straight included in the model, but it is a good comparison point as it includes notable parts of the outsourced maintenance.

Also, as TOL-2008 Allows single company to have multiple secondary industries, some of the industries that include some but not a lot of maintenance services are 70 Activities of head offices; management consultancy activities, which includes holding companies, 71 Architectural and engineering activities; technical testing and analysis, which includes planning and managing maintenance activities. Also, 62 Computer programming, consultancy and related activities and industry 63 Information service activities might include automation and electrical maintenance activities.

Indicators used in this model were defined in chapter 2.1 and primary indicator is maintenance costs per turnover. This indicator is easier to use with public data than maintenance costs per production equipment value, as turnover for different industries are public information, while data on equipment value cannot be easily gather. Still, if available, estimates on maintenance costs over production equipment value are gathered, as they are a good comparison point to verify the other indicator. Method used for this part of model is summarised in Equation 1.

$$\textit{Maintenance cost} = \textit{Avg. maintenance cost per turnover} * \textit{Annual turnover of Industry} \tag{1}$$

Two major factors affecting the accuracy of results of the model are both accuracy of turnover estimate and accuracy of average maintenance indicators. Both used indicators and development of turnover during the modelling period can be seen in Appendix 2. Both factors have some inaccuracy, but noticeably harder one to estimate is the maintenance cost indicator. Values for this indicator are hard to come by, as many companies do not publicly talk about their maintenance costs. Also, calculating what are maintenance costs can vary on the company level, as what are counted as maintenance activities can vary from company to company. This might somewhat compromise the accuracy of calculations. Also, amount of maintenance cost varies depending on multiple factors like age of equipment, economies of scale in maintenance and maintenance strategies implemented by different companies, which makes average indicators inherently inaccurate.

Maintenance cost also vary greatly between different industries, but for example in Austria they are generally estimated between 1-12 percent depending on the industry (Dankl & Stuber, 2010). In Finland, predicator of Promaint, Kunnossapitoyhdistys (2003) has estimated maintenance costs to be from 2-14 percent of sales depending on the industry.

One of the latest estimates on different indicators for Finnish companies has been done by Komonen (2005) with yearly estimates gathered from industries. From reported annual numbers an average over 3 years was calculated. These numbers are shown in Table 2.

Table 2 The indicator averages for some industries (Komonen, 2005)

	Costs / Turnover (%)			**Costs per value of production machinery (%)**		
	2000-2002	2001-2003	2002-2004	2000-2002	2001-2003	2002-2004
10 Manufacture of food products	3,3	3,5	3,9	3,4	3,7	4,1
17 Paper and paper products	4,8	4,8	5,1	4,2	4,3	3,5
19-22 Chemicals, rubber and plastics	5,8	6,3	6,3	2,9	2,9	2,9
23 Non-metallic mineral products	3,3	-	-	2,8	-	-
24 Manufacture of basic metals	4,5	4,5	4,8	3,7	3,4	3,3
25-28 Machinery and equipment	2,1	2,4	2,3	2,6	2,7	2,8
351 Energy production	-	-	-	1,8	1,8	-

Newer estimates for maintenance costs of different industries are searched mainly from earlier research and especially different master thesis done for companies are a good source for single companies. Other important source for estimating and verifying maintenance costs are statistics gathered by industry organisations.

To support modelling a questionnaire about maintenance indicators and markets was made. In this questionnaire estimates on maintenance indicators and maintenance methods used by different companies were requested. Relatively good answers were received for some industries, and some estimates from other sources could be verified.

In the questionnaire on top questions about maintenance indicators there were questions about general trends of maintenance. Questions were asked on for example, on what kind of maintenance is concluded in the companies. Also question on how much maintenance personnel are employed by companies in different industries. Complete list of questions is given in Appendix 1. Questionnaire was done in Finnish. From these answers a wider analysis on changes of domestic industrial maintenance market can be done. These answers can be used to explain why changes in the market have happened and it can be useful in predicting the future domestic market changes.

On average, the accuracy of this part of model is quite good. Turnover statistics used are as accurate as can be and use of average indicators should not compromise the accuracy of the model, even though maintenance costs of single companies might vary greatly from the average. Good comparison points to earlier average estimates are found from earlier research, which show that similar methods have been used earlier. One of the largest issues is that definition of maintenance costs varies from company to company and indicators are based on large companies as answerers to questionnaire came mostly from large companies and publicly available research is mostly done for large companies.

3.3 Maintenance in infrastructure

There is no uniform way of modelling maintenance in infrastructure, as infrastructure is composed of multiple different assets. Most of the infrastructure in Finland is owned and operated by government or majority government owned companies, which can be modelled relatively easily trough public information. On the other hand, parts of infrastructure like water treatment facilities, power plants and district heating, are operated by private companies which make estimating them more complicated.

Major components of infrastructure modelled in this study are, road-, rail- waterway networks, power grid, power and heating plants, district heating network and non-industrial water treatment facilities. Largest single part of infrastructure not taken in model is house stock. Other notable part of infrastructure not modelled is telecommunication network. These are not modelled as there is no suitable way to model telecommunication network and housing stock is not truly part of infrastructure as only a small part of housing stock is publicly owned or used.

The size of maintenance in housing stock is also multiple times larger than all other infrastructural maintenance and changes in housing maintenance would skew the estimates and results for this part of the model. Also, most of housing maintenance is done by private people as almost half of housing stock. This private maintenance is also partly done by owners themselves, which is not part of commercial maintenance, that this study is made to estimate.

Whole stock being valued at 460 Billion euros most of which is owned by private citizens. 60 billion of housing stock is owned and operated by industry, which is included in the previous part of the model, as industries don’t publicly separate amounts of maintenance done to production equipment and building stock. Last part valued at 45 Billion is true publicly owned infrastructure. It is hard to estimate real sum used only in this part, as funding for these public building come from multiple different sources and are not publicly available. (Soimakallio et.al., 2017)

Road, rail and waterway networks are modelled simply by looking for data of maintenance expenses for different years in budget of Finnish Transportation ministry. (Finnish Transportation ministry, 2013, p.14-15) This estimates only includes main roads maintained by government level. Maintenance done by different municipal level governments and maintenance done to private roads are not included in the model. The length of modelled road network is about 78 000 km and includes 14 800 bridges, while network of roads on municipal level is 28 000 km, which is not included in the model. On the other hand, there are 240 000 km of private roads. Large part of these private roads has noticeable less maintenance done to them and traffic and large parts of them are forest roads primarily used for logging or other this kind of activities. (Soimakallio et.al., 2017, p.21; ELY-keskus 2018)

All major rail- and waterways are maintained by Transportation ministry. There are some railroads and harbours operated by industries, but maintenance costs for these are included in the industrial part of this model. So, for these parts an estimate on ministry budget is accurate. Only major factor of this part of infrastructure not in the model, is maintenance done by non-industrial harbour operators.

The power grid can be divided into two parts, transmission grid and distribution grid. Transmission grid is high voltage grid operated and maintained by mostly government owned company Fingrid. The distribution grid is operated and maintained by multiple local and national companies. In the model the transmission grid is relatively easy to estimate, as Fingrid has published data on its own maintenance costs. There has also been estimates made on maintenance costs in distribution network and these both estimates can be used in the model.

Unlike Komonen (2005) power and heating plants are not modelled trough maintenance cost over production equipment value. In this study maintenance costs for power and heating are modelled trough operating and maintenance costs (O&M costs) for produced electricity and heat. These estimates are gathered from report by Tarjanne & Kivistö (2008) and because they include both operating and maintenance costs share of maintenance expenditures must be estimated from overall O&M costs. Statistics Finland gathers estimates for produced energy by different fuels. These statistics are divided in electricity production and heating production. Equation for these two parts is shown in Equation 2.

$$\textit{Maintenance in power plants} = \sum (\textit{Annual amount of energy produced by fuel source} * \textit{Average maintenance cost for fuel source}) \quad (2)$$

In Finland district heating network is small and modern and the maintenance costs for this part of infrastructure are relatively small. Annual amount of maintained is about 50 to 70 kilometres and about 200 kilometres more network is built annually. (Soimakallio et.al., 2017, p.32)

Maintenance costs are estimated to be about 260 € per metre at Jyväskylän Energia Oy and they estimate length of maintained network to be about 2 kilometres annually (Ala-Porkkunen, 2015, p.78). Comparing this amount to length of their network 450 km, provided by statistics of Energiateollisuus ry (2016), gives an annual replacement rate of 0,5 percent of entire network. Comparing this amount to whole network length gives estimated maintained length of 73 kilometres, which is in the same area as estimate of Soimakallio et.al. (2017).

An estimate on the size of the network and the book value and maintenance expenses of Finnish non-industrial water treatment network and facilities has been done in ROTI-report. (Soimakallio et.al., 2017, p.32-34) Similar information and estimates on maintenance in water treatment facilities are provided in other studies. (Maa- ja Metsätalousminiesteriö, 2008; Laitinen & Kallio, 2016). These estimates are used in this study to estimate maintenance amounts in non-industrial water treatment network.

Overall accuracy of this part of the model can be said to be relatively accurate. There are noticeable parts of infrastructure not included in the model. Multiple parts of the model are based on estimates done by other organisations or in other studies. Accuracy for these parts like water treatment are hard to estimate, but these estimates are commonly cited as accurate estimates, so they can be used.

As there are some noticeable parts excluded from the model it limits the accuracy of the model. Lack of municipal road maintenance costs is the single largest issue in the model.

Also, maintenance of energy combined energy production of industry and heating production from forest industry's industrial waste liquors are not included in this part of the model as maintenance costs from them should already be included in the model's industry part.

Many parts of the model can be directly sourced as maintenance expenses for the whole part of the model, like road-, rail- and waterway networks and power grid. While only part that is built on industry indicators is electricity and heating production. Which is based on annual energy production and average O&M-costs.

3.4 Maintenance in export market

In this part of the model an estimate on the size of Finnish maintenance export market is built. The model is done by analysing financial statements, annual reports and other material published by largest Finnish companies. From these sources the amount of maintenance turnover and the export turnover for the companies is estimated and from these factors an estimate for company level maintenance export sales is done. Market level estimate is gathered from these company level estimates. Common generalisation for equation used for most companies in this part of model can be seen in Equation 3.

*Maintenance export sales = (Sales – Sales to Finland) * (Share of maintenance sales of overall sales)* (3)

Model is extended from last available year (2016) to past four years. This is done to find changes in recent years both on company and market level. Model is also limited to only largest companies as good enough estimate can be done based only on largest companies. Initial list of companies to be estimated were taken from Bureau Van Dijk's Amadeus – database. Database search was done with criteria of companies based in Finland and a revenue of 150 Million euros.

This search gave a list of 501 largest companies registered to Finland. This list was checked trough and limited to 49 companies to be checked further. From these companies relevant data was found for 22 companies, as some companies initially expected to have notable maintenance exports didn't have any and some companies chosen were subsidiaries of other companies in the list. During the estimating process two more companies outside the list were added to the model, as they had notable maintenance exports and relevant position in the industry. At the end 24 companies were estimated in the model.

In the model exports are defined as both direct exports from Finland and income from maintenance work done abroad by foreign subsidiaries owned by Finnish companies. This choice must be made because most companies define data on their annual reports only on corporate levels and do not usually specify direct exports from Finland.

Data used in the model can be estimated to be good enough for an accurate estimate on the overall size of market, as especially largest companies provide exact data about exports and about share of maintenance services. Publicly traded companies provide most data as they must convince investors to invest into them. Largest issue with data from publicly traded companies is differences in counting and reporting sales of services and products.

Data from publicly traded companies is the best data available for the model, as for foreign owned Finnish companies in the model, like Andritz Oy, maintenance exports must be estimated trough foreign group level data and other sources. Still estimates made for these companies should be accurate enough for purposes of this study.

Privately owned companies provide noticeably less data, which makes estimate less accurate. Luckily, none of the largest companies are not in this group so it doesn’t compromise the accuracy of the model. Few companies that have not published their export or maintenance sales data have been estimated with other sources like SKOL ry’s (2017) export data for Pöyry and Neste Engineering Solutions.

Even though number of companies in model is relatively low, estimate should give accurate picture about the size of the market. Accuracy on the scale of export market should be good enough as largest companies in the model have the most accurate estimates and from these largest companies five largest companies sum up to 9,5 Billion euros, which counts to 77 percent of the Finnish maintenance exports. Companies left out of the model are small compared to largest companies and smaller companies usually only have maintenance export sales of tens of millions. So not having smallest companies in the model, won’t greatly affect the accuracy of the model.

3.5 Future of maintenance market

All different parts of the model include estimates for changes that are predicted to happen in the few next years. Industry and mining are modelled trough external estimates on changes in industry turnover. For infrastructure there are some future estimates made for various parts of the model and there are budgets available for different parts of the infrastructure. For the export market future trends seen by modelled companies are analysed and a trendline for market is made on the averages of the modelled years.

In this study the scope of accurate future estimates is limited to next two years. Many estimates and some used budgets are made only on these two years and there are not accurate estimates on a longer scope, so this time frame must be chosen. As data for 2017 is not yet widely available at the time of writing, it can’t be used as a primary year of the model. Still trends of modelled years and trends of next two years are used as a basis to show possible trend up to year 2020, if the trends do not change.

Lehto and Lähdemäki (2016) have modelled future changes in Finnish economy. They have estimated future changes in production value of industries and give estimates on most of the modelled industries. These estimates are used to estimate development of turnover for each industry and trough these changes in the market can be analysed.

For transportation infrastructure Ministry of Transportation has published budget up to 2018. This budget can be used as an estimate on transportation network for next two years. While other parts of infrastructure are harder to model. Lehto and Lähdemäki (2016) have also estimated changes in amount of building and trough these estimates changes in maintenance of housing stock can be estimated. For other parts of infrastructure changes in amount of maintenance are harder to estimate. Estimates on other parts infrastructure are analysed in chapter 4.4.

For the export market future trends seen by modelled companies are analysed. These trends are looked for in newest reports and publications, even while maintenance export sales for 2017 are not taken as a primary modelling year. Sales amounts for 2017 are used to confirm the results of the future predictions. Which is made on the average growth of exports during the modelled years.

Estimates for the future development are shown with a confidence interval of 90 percent calculated on the standard deviation of earlier modelled years. This means that positive and negative estimates are also shown.

4 DOMESTIC MAINTENANCE MARKET

4.1 Analysis on industry and mining

For industry and mining the domestic maintenance market size is modelled to be between 4 and 4,5 Billion euros. The market has been relatively stable and on a lowering trend over the period of four modelled years. This and trend for market is seen in Figure 9. Values for every year and industry can be seen in Appendix 2.

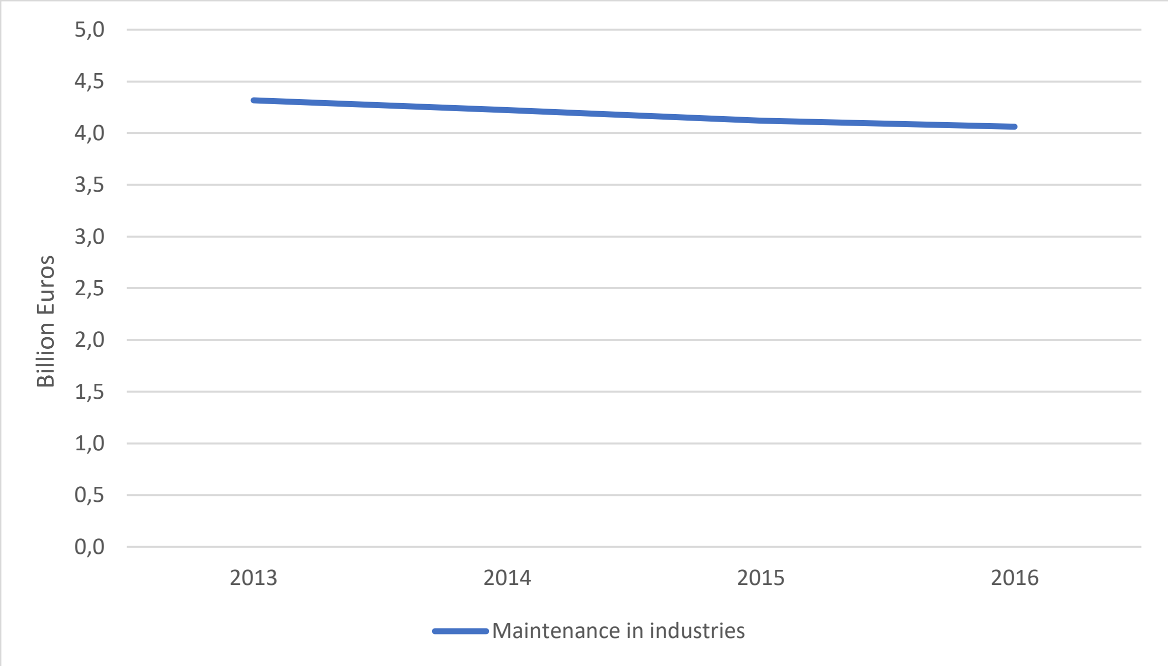

Figure 9 Maintenance costs in Finnish industries

Maintenance cost estimates for each industry can be seen in Appendix 2, along with sales for each year and indicators used for each industry. This estimate can be tested by comparing the estimate to the similar estimate for French market. In France the industrial maintenance market is 1 percent of Gross Domestic Product (GDP) (Pichot, 2017). This estimate of 4,1 Billion euros is 1,9 percent of Finnish GDP, which is slightly more than the French estimate, but still is in a similar range.

The estimate of 4 Billion is about 500 million euros more for Industry and mining than estimate based on numbers of year 2001 done by Kunnossapitoyhdistys (2003). This change can both be based on changes of industry average indicators and in change of sales. Järviö (2007 p. 15) has argued that amounts of production and maintenance costs should grow in the future. But, according to him production amounts should grow faster than maintenance costs, which would be caused by lowering of maintenance costs in the future.

In the Table 3 there is a comparison between current average indicators found in research of this study and earlier estimates on averages of Finnish industries.

Table 3 Comparison between older indicator estimates

Industry	**Current cost per industry (%)**	**Earlier estimates on costs per industry (%)**
Forest industry	4–5	5,1–6,7
Metal industry	2–6	2,1–5,3
Chemistry	3,5–4	4,1

As can be seen from the Table 3 indicator averages, that have been gathered from kunnossapitoyhdistys (2003) and Komonen (2005), have lowered as Järviö (2007) has expected. This drop can be explained by multiple factors like larger use of predictive and proactive maintenance methods and by maintenance budgets being cut after the market crash of 2008. Of course, cutting maintenance costs would lead to growth of maintenance backlog in these factories and to larger number of unexpected failures. True reasons for lowering of average maintenance costs per sales can only be speculated on and should be estimated further. These findings correlate well with the earlier research like Blache (2009a) and Kunttu et al. (2010), which have also found newer average indicators to be lower than estimates in the early 2000s.

The variation of estimated maintenance amounts between different years can be explained by changes in sales of the industry during the modelling period in Finnish manufacturing industries. As average indicators are static during the modelling period, only variable is size of sales. The sales in industries have dropped noticeably during the modelling period. Overall sales amount has dropped about 13 Billion euros from 136,7 Billion euros in year 2013 to 123,3 Billion euros at 2016. Still sales in 2016 are about 20 percent larger than in early 2000s as sale amounts back then were about 104 Billion.

As overall changes in model’s sales are composed of sales in different industries. So, it is important to analyse the changes in different industries. Changes of sales during the modelling period in different industry groupings can be seen in Figure 10.

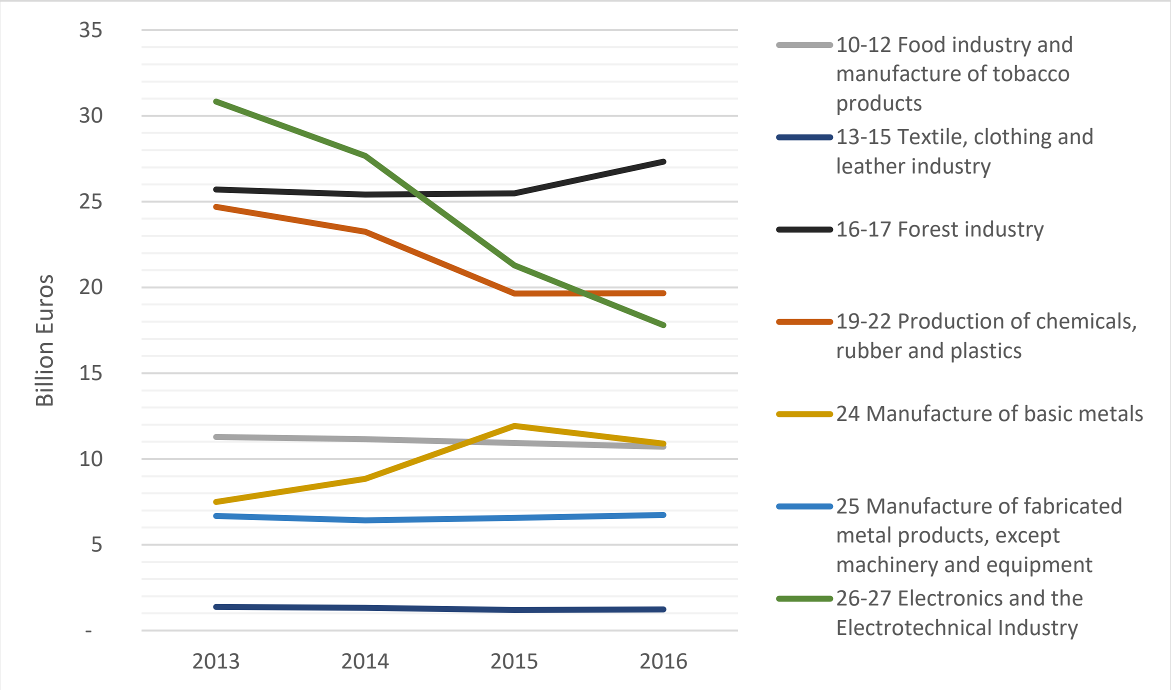

Figure 10 Development of sales of different industry groupings

As can be seen in the Figure 10 the most notable drop has happened in electronics and the electrotechnical Industry. This industry has lost 13 Billion in turnover over the modelling period. Other notable drop has been in Production of chemicals, rubber and plastics and more exactly in Manufacture of coke and refined petroleum products, which is a subindustry of in Production of chemicals, rubber and plastics grouping. Manufacture of coke and refined petroleum products has lost 5,4 Billion euros in sales during the modelling period.

The drop in manufacture of coke and refined petroleum products can be explained in changes crude of oil price as had noticeable drop during the modelling period. The crude oil price was around 110 € for a barrel during 2013 and in the end of 2014 average price had dropped to 50 € per barrel. At the lowest price was at January 2016 at about 30 € per barrel. (Macrotrends.net, 2018)

Electronics and the Electrotechnical Industry has had a steady lowering trend in sales ever since the market crash of 2008. This drop is not only caused by price changes in electronic products, but in Finland also production amounts for this industry has also lowered steadily. (Teknologiateollisuus, 2018a, p. 6) This means that both production amounts and sales have lowered, which results in real changes in maintenance amounts in the industry as most likely capacity needed to be maintained has lowered as production amount has lowered.

Largest growth has happened in manufacture of basic metals, which has grown 3,4 Billion euros in the modelling period. According to Teknologiateollisuus (2018a, p. 8) almost all changes in sales of manufacture of basic metals is caused by changes in prices of metals and not by new capacity.

At the same time sales of forest industry has grown for about 2 Billion euros. The common trend in past years in Finnish forest industry has been that intense competition in the industry with smaller demand for paper products has forced companies to close unprofitable capacity. For example, alone in 2015 capacity of paper industry was cut by 760 000 tons (Lehto & Lähdemäki, 2016).

Recently demand for pulp and other forest products, excluding paper, has grown, which has caused growth in investment and sales of industry. Maintenance in this industry can be expected to grow in future years as there is notable new investments in this industry are realised. There are three new pulp or biorefinery plants planned to be built in Finland in the close future. (Lehto & Lähdemäki, 2016)

As can be seen in some industries, like manufacture of coke and refined petroleum products and manufacture of basic metals, market price of product or raw materials can cause substantial changes in annual sales. These changes in sales and prices effect the results of the model immediately. This change in the model might be larger than true change in maintenance cost, especially when sales grow, as model predicts maintenance costs to grow in same way. On the other hand, when sales lower the model reacts in the same way and this might be more accurate as cost savings must be done to secure profitability and maintenance can be a tempting activity to cut to achieve cost savings. Also, model reacts fast to new capacity and sales, which might not be accurate, as maintenance costs for this new equipment might differ from mature equipment. As speculated in chapter 2.2 there is no clear consensus on real maintenance costs of new equipment, but most likely as there is infant mortality in new equipment more reactive maintenance is needed for new equipment, while older equipment needs larger modernisation maintenance to prevent degradation of productivity.

As can be seen on average maintenance indicators have lowered, when compared to earlier estimates and amount of sales are noticeably larger than in early 2000s. These changes have not nullified each other, and the amount of annual maintenance costs have grown. The annual sales have grown faster than indicators have lowered, which has caused growth in the amount of money used in industrial maintenance.

To understand the size and economical effect of maintenance market, the worker count in maintenance is important to be known. Estimate from early 2000's was that in total domestically there were 200 000 maintenance workers, which of 50 000 worked in industries and 15 000 of these were working for outsourced service companies. (Kunnossapitoyhdistys, 2003)

Overall trend after the estimate of Kunnossapitoyhdistys is, that the number of employees in have lowered in industries. Meanwhile amount of sales have grown. In estimate of Kunnossapitoyhdistys (2003) overall industrial personnel amount was 475 000 persons, while current estimate of Statistics Finland is about 300 000 persons. (Statistics Finland, 2018)

Accurate estimates on amount of maintenance personnel are hard to gather, as even who are counted as maintenance personnel varies from company to company and from industry to industry. In the questionnaire share of primary maintenance personnel was asked and answers varied from 17 to 40 percent in industrial setting. Also, the level of outsourcing varies on the company level as lowest answer was 5 percent and highest answer was 100 percent of maintenance being outsourced.

This high variance in answers makes estimates inaccurate, If, an estimate with 20 percent of personnel being maintenance personnel is made, which is the range of answers from questionnaire and average of answers of Cuervo and Tormos (2016). This would mean that there are about 60 000 maintenance professionals in industries. This is more than in early 2000s and seems high, as it is known from answers, that the total amount of maintenance personnel has lowered in companies but share of maintenance personnel might have grown.

This estimate would show that probably share of maintenance personnel is higher than earlier, but as total amount of personnel employed by companies has lowered drastically more realistic estimate would be from 40 to 60 thousand persons in industries. The amount of outsourced personnel has probably grown through servitization of production companies and through trend of outsourcing in maintenance. This hypothesis is supported by the share internal maintenance personnel costs having lowered in answers of the questionnaire when compared to earlier estimates.

In the estimate of French industrial maintenance market about 36 percent of the industrial maintenance costs come from services, this gives estimate of 8 billion and 51 000 outsourced maintenance personnel (Pichot C., 2017). From answers of the questionnaire

34 percent are service costs, this average would give outsourced market of 1,4 billion euros and 9 300 domestic outsourced maintenance personnel in Finland.

Group 33 Repair and installation of machinery and equipment had a worker count of 15 831 in 2016. This group can be divided further, and subgroup 331 Repair of fabricated metal products, machinery and equipment had a worker count of 11 460. (Statistics Finland, 2018) This statistic would support the estimate of about 10 thousand outsourced maintenance personnel in industries. Still this group does not most likely include all outsourced maintenance personnel and groups 62, 63 and 72 might include some maintenance personnel, which would mean that estimate of ten thousand outsourced personnel might be in the low end possible number.

In Figure 11 share of maintenance work done by the type of maintenance activity is gathered from the answers of the questionnaire. Share of Mechanical maintenance has lowered, and electrical and automation maintenance has grown when compared to earlier estimates in Finnish industries. Electrical and automation maintenance has grown from 20 percent to 33 percent and mechanical has lowered almost as much from 63 percent to 45 percent. (Kunnossapitoyhdistys, 2003)

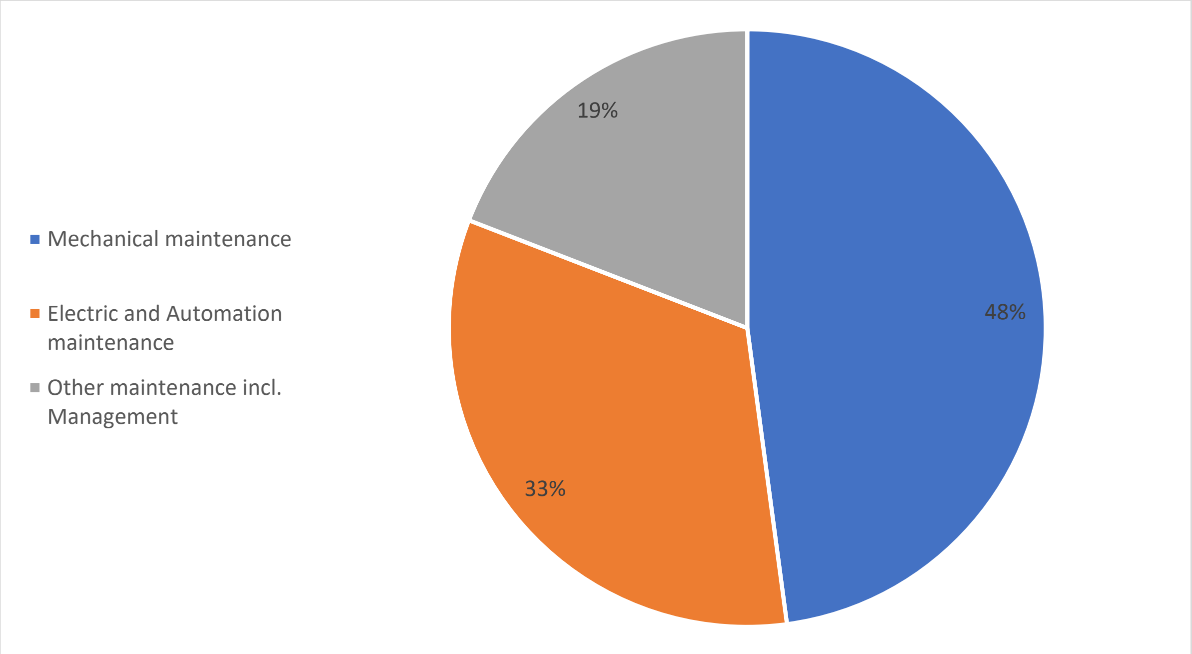

Figure 11 Maintenance method averages in industries

This change towards electrical and automation maintenance can probably be explained by development of production equipment. As production has become more automated has maintenance turned more towards electrical maintenance. This has lowered the share of mechanical maintenance, while management and other activities have remained the same.

In Figure 12 shares of corrective and preventive maintenance is shown. In estimate of Kunnossapitoyhdistys (2003) corrective maintenance had 32 percent and preventive 54 percent and 14 percent of other maintenance activities. Differences between earlier and this might be explained by preventive maintenance being split into 2 parts preventive maintenance and improvement. On top of these two there was another activity of planned maintenance.

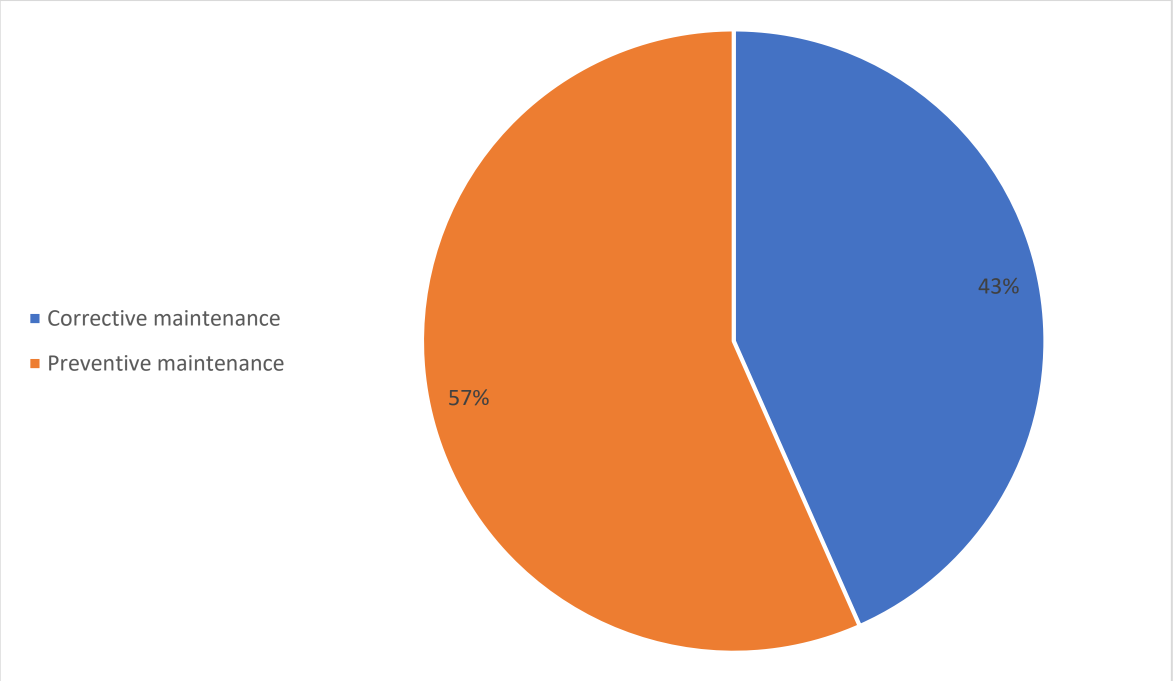

Figure 12 Maintenance method averages in industries

Share of corrective maintenance is surprisingly large in this questionnaire. Blache (2009a) had gotten an answer of 12 percent for share of corrective maintenance while preventive and predictive summed up to 88 percent. Earlier Finnish research had 25 to 35 percent of corrective maintenance and rest being divided between preventive, improvement and other maintenance work. (Kunttu et al., 2011 p. 22) But on the other hand, questionnaire among mainly Spanish companies where shares of maintenance work between preventive, corrective and maintenance in turnarounds was asked got similar answers where corrective maintenance often had a similar high share between 30 to 40 percent. While preventive hovered 35 to 65 percent and turnaround maintenance was between 5 and 20 percent. (Cuervo & Tormos, 2016)

One reason for large differences to earlier research might be explained by large variance of answers between different answerers, in Table 4 variance, minimum and maximums for each of the answer groups are shown. Also, the number of answerers is relatively small and many of the answerers were service providers, which might explain the larger share of corrective maintenance compared to preventive maintenance.

Table 4 Statistics on maintenance methods

	Corrective maintenance (%)	**Preventive maintenance (%)**
Average	47	53
Variance	26	26
Min	10	25
Max	75	90

Overall industrial maintenance setting has changed in a similar way as expected. Maintenance costs per sales have lowered as expected and number of persons employed have also most likely lowered. Maintenance fields have turned more towards electrical and automation maintenance as share of mechanical maintenance has lowered. Most surprising factor in the model and answers on the current stage of maintenance markets was the high share of corrective maintenance in the answers.

4.2 Future predictions in industry and mining

In the questionnaire there was an open question about future of maintenance. There was a request to ponder on possibilities, changes and risks that future will bring to maintenance. Most answerers touched on the subject digitalisation and growth of predictive and preventive maintenance as the major changes in future. Also, analytics and remote control and monitoring were seen as the most notable possibilities in the future.

There was no consensus on if there will be a trend of outsourcing or insourcing. Some expected number of own maintenance personnel to lower while others expected production companies to return more back to having larger internal maintenance departments. This same dichotomy has also been seen in scientific literature.

Major risks also included loss of tacit knowledge as a generational shift is happening with workforce, this means that a lot of knowledge can be lost when large older generations retire. Also, amount of technical knowledge needed for new methods is high, which will make finding suitable workers harder. Lack of education for maintenance is also seen as a risk contributing to the lack of suitable maintenance workers.

As mentioned in chapter 3.4 Lehto and Lähdemäki (2016) have estimated changes for production value of most modelled industries. These estimates were used as a basis for estimating future sales and trough this estimating maintenance costs for different industries. Estimates for all industries can be seen in Appendix 3. These estimates show that generally total amount of sales in industries will grow and so maintenance costs will grow slightly. Total amount of sales can be estimated to grow in future from 123 Billion in year 2016 to 126 Billion in year 2017 and 128,5 Billion in 2018.

The economic growth can be expected to keep continuing in the future. On average Lehto and Lähdemäki (2016) estimate, that sum of different industries grows from 2 to 3,7 percent between years of 2016-2018. Teknologiateollisuus ry (2018b) estimates that on average industries will continue growing 3 percent annually between 2018 and 2023. This estimate that stable growth in industries will continue is used as a basis to expand currently predicted trends to the year 2020.

Sales in most industries will grow in future years except for TOL 2008 group 13-15 Textile, clothing and leather industry, which will continue to outsource production to lower cost countries. Also, electrical communication and lowering demand for printed products will cause industry 18 Printing and reproduction of recorded media to continue to shrink. Third industry to shrink during the next years is 19 Manufacture of coke and refined petroleum products which is based mostly on price development of crude oil and by changes in production of Neste, which is the largest company of the industry. (Lehto and Lähdemäki, 2016)

Forest industry, which is the largest industry group in Finland, has relatively positive trend, excluding printing, for the next two years. Forest industry is expected to grow by about 5 percent for 2017 and slightly diminish by 1 percent the year after, while pulp and paper production is expected to grow by just over 2 percent during the both years. (Lehto and Lähdemäki, 2016)

Industry 20 Manufacture of chemicals and chemical products and 22 Manufacture of rubber and plastic products are largely tied to demand from other industries as they usually process raw material further for industrial use. These chemical industries have new capacity to be realised in 2016 to 2018 and so sales in industries will grow. Also, industry 21 Manufacture of basic pharmaceutical products will have noticeable growth in future years as it will continue to grow. The small size of this industry makes changes in sales seem larger as in 2018 growth of 12 percent translates to growth of only 275 Million in sales. Industry 23 Manufacture of other non-metallic mineral products will also grow in next few years.

Metal and Machine industries have had relatively positive trend in recent years. Only sales in Electrical industry have lowered during the modelling period, while sales in other industries have grown. Lehto and Lähdemäki (2016) expect sales in all metal and machine industries, from 24 Manufacture of basic metals to 30 Manufacture of other transport equipment, to grow in future years. The growth for different metal and machine industries are listed in Table 5.

Table 5 Output changes for certain industries (Lehto & Lähdemäki, 2016, p.10)

Industry:	**Growth in 2017 (%)**	**Growth in 2018 (%)**
24 Manufacture of basic metals	3	2,2
25 Manufacture of fabricated metal products, except machinery and equipment	3,7	2,9
26 Manufacture of computer, electronic and optical products	2	2,3
27 Manufacture of electrical equipment	2,6	3,4
28 Manufacture of machinery and equipment.	1,4	3,8
29 Manufacture of motor vehicles	25,1	1,6
30 Manufacture of other transport equipment	3,9	18

Most notable changes are the ones in 29 Manufacture of motor vehicles and 30 Manufacture of other transport equipment. The change in manufacture of motor vehicles can be explained by single investment by Valmet Automotive in a new production line. Valmet Automotive is the largest player in the industry and changes in their sales cause notable changes in sales of industry. Manufacture of other transport equipment includes building of ships and rail equipment. Change in industry sales largely come from all Finnish shipyards having their order books full and alone Turku Meyer will have 20 percent more sales in 2018. (Lehto and Lähdemäki, 2016)

Future maintenance costs are only modelled trough changes in sales. As in this model changes in maintenance indicators are not modelled, but changes in these indicators must be followed in the future. So, these indicators must be actively updated in the future as model is updated by Promaint. Updating maintenance indicators will also make model more accurate.

Total amount of maintenance in industries can be expected to grow as total amount of sales keeps growing during next few years. Estimate for year 2017 is 4,2 Billion euros and for 2018 maintenance costs are estimated to be 4,3 Billion euros. In Figure 13 these estimates are shown with a confidence interval calculated with a confidence factor of 90 percent.

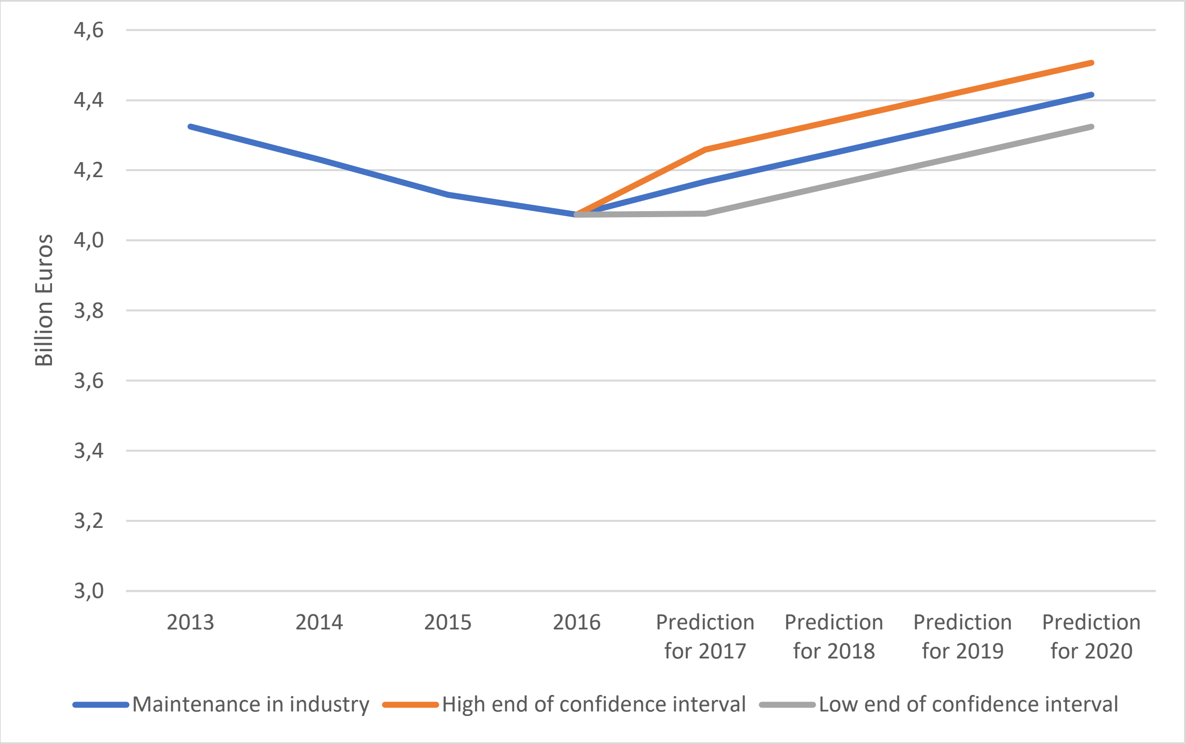

Figure 133 Future prediction on industrial maintenance amounts

From Figure 13 can be seen, that trend of lowering size of industrial market will turn around in 2017. Even the lower end of confidence interval turns towards a positive trend. High end of confidence interval will be about 4,34 Billion euros in 2018 while low end of confidence interval is about 4,16 Billion euros. Confidence interval in this part of the model is relative small, which is caused by deviation of data set being relatively low.

4.3 Analysis on infrastructure

The entire maintenance market in infrastructure sums up to approximately 2,1 Billion euros in the year 2016 without maintenance of housing stock. With maintenance in housing stock it sums up 9,7 Billion euros, which is still noticeable less than 11,7 Billion euros estimated earlier (Kunnossapitoyhdistys 2003). This difference might be explained by older estimate and this model having different ways to estimating some parts of infrastructure and this model not including maintenance of communications network.

The development of market in the past four years can be seen in Figure 14. Overall trend for maintenance market in infrastructure has been growing and in past four years amount of invested money in infrastructure. Similar trend has been also in housing stock as more and more money has been used in maintenance of housing stock during the modelling period.

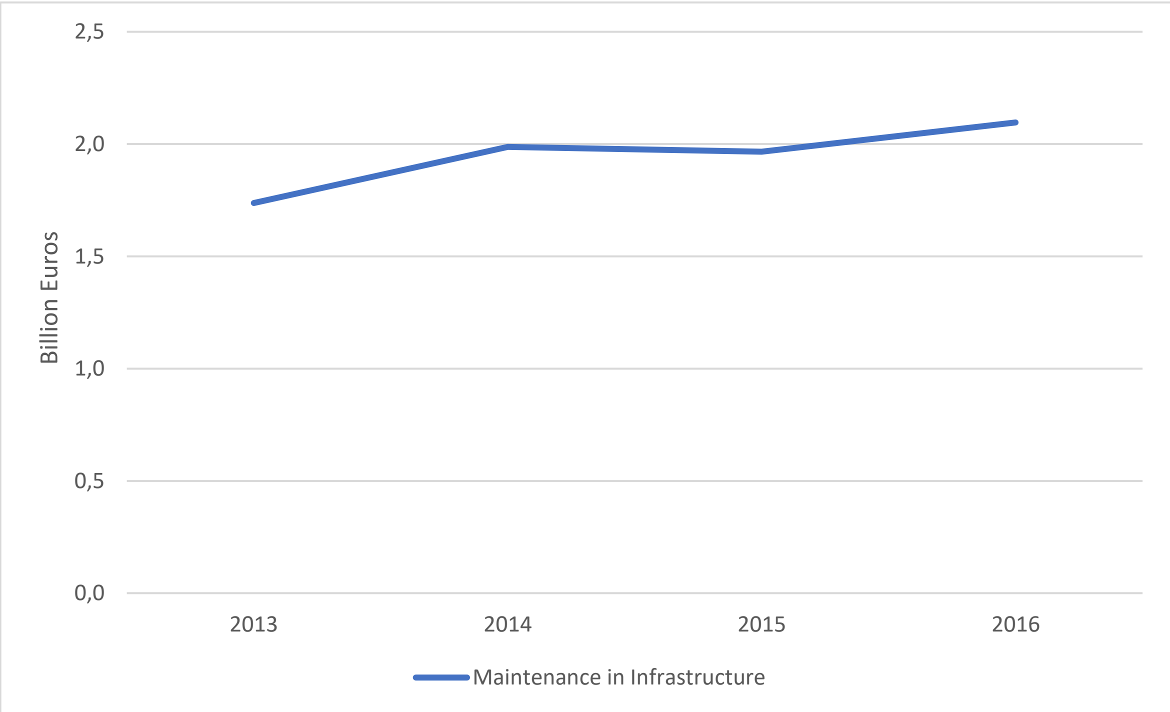

Figure 14 Size of maintenance market in infrastructure

In the Figure 15 annual estimates for each different asset of infrastructure can be seen. Also, values for each year for all different assets are shown in Appendix 4. As can be seen most aspects of the modelled results have been relatively stable and infrastructure can be seen to be set in three different size groups which are: about 500 million, about 300 million and under 100 million. Most notable growth has been in road, rail and waterway infrastructure. This growth can be explained by the current Finnish government investing larger amounts of money to these assets. Partly this is done to combat the growth of maintenance backlog in transport infrastructure. This change in maintenance amounts to combat maintenance backlog can be seen to have caused maintenance in rail network to switch size groups. Other asset that might change its cost group due to growing maintenance backlog would be water treatment as there is a need for 200 million extra funding to reach sustainable levels (Soimakallio et.al., 2017, p.34).

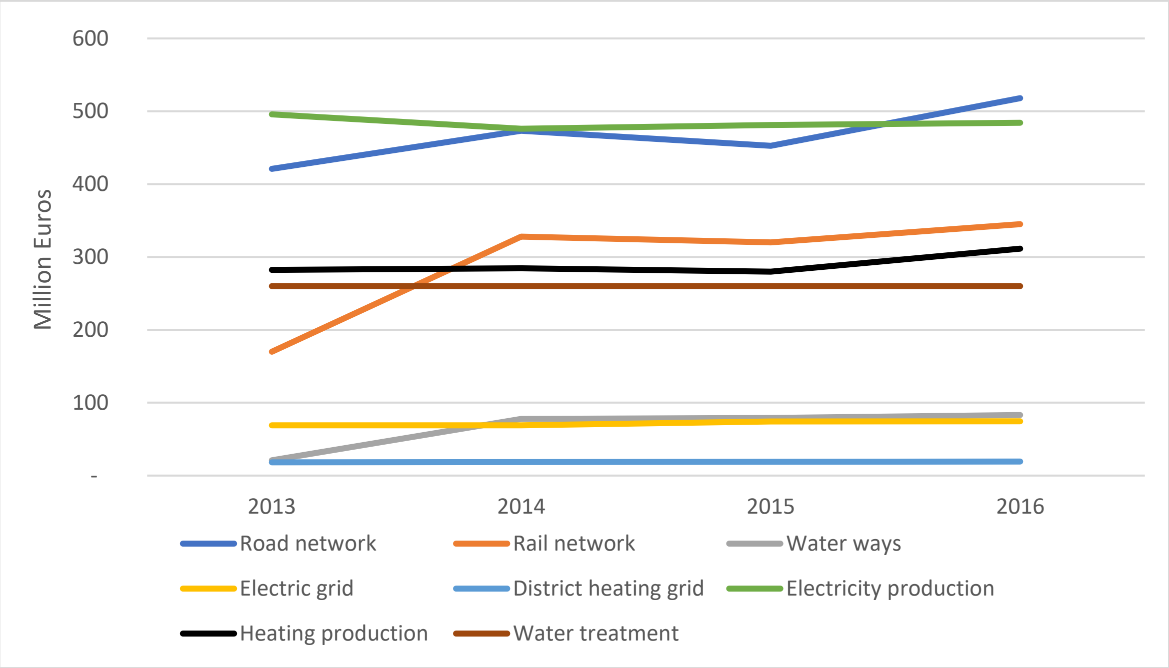

Figure 15 Maintenance costs in different assets

The transportation network infrastructure has had the largest amount of maintenance budget added during the modelling period and larges growth is clearly in rail network. Large part of this changes has come from added budget to combat maintenance backlog. Maintenance budget in rail network has almost doubled from 180 Million to 350 million between years 2013 and 2016. In past four years the amount of maintenance in road network have grown by 100 Million euros to just over 500 Million euros. This can be largely explained with added government funds to combat growth of maintenance backlog.

Finnish government invests under 100 Million euros annually in maintenance of waterways. This sum does not include maintenance of done in harbours, but maintenance done in harbours is not large. For example, by volume largest non-industrial harbour, Helsinki harbour, had 79 percent of person traffic and 26 percent of cargo tonnage in Finland in 2016, but still the harbour has only about 33 maintenance personnel and annual investments of only few million in maintenance. (Helsingin Satama, 2018)

Maintenance cost combined in heat and electricity production are around 800 Million euros. Maintenance costs in both heating and electricity production have stayed relatively stable, as there has not been large changes in Finnish energy production assets. Most of the new investments have been in wind and solar energy production and scale of these plants is small compared to the whole energy market.

Power grid is divided into two parts which are distribution and transportation grids. Transportation grid is operated and managed by Fingrid. They publicly reveal their maintenance costs for transportation grid and reserve power plants. These maintenance costs have grown in recent years. During the modelling period these maintenance costs have grown from about 19 to 24,5 Million euros. (Fingrid, 2016; Fingrid 2018)

Maintenance done in distribution grid are estimated to be 50 Million annually. On top of maintenance large parts of distribution grid are being replaced by underground cabling, which requires less maintenance and are less likely to fault than over ground lines. (Energiavirasto, 2015, p. 43)

District heating network has had annual maintenance of about 20 Million euros. During the modelling period maintenance costs have grown slightly, as maintenance network length has grown annually, and the network has aged.

Water and sewage treatment network have had only 120 Million euros of maintenance investments annually and this sum is extremely low compared to need to stabilize growth of maintenance backlog. This annual need is estimated to be 320 Million. A structural change must be made in Finnish water treatment network as funding and need do not meet. This maintenance funding gap will cause more and more dangerous failures, which cause risks for consumers. Also, growth of maintenance costs will raise the costs for consumers, as network is funded through customers. (Soimakallio et.al., 2017, p.34)

On top of 120 Million euros of maintenance in network. There are estimates on operation and maintenance costs for water treatment facilities, which are annually about 484 Million euros (Lapinlampi, Raassina, 2002) and annual investments in whole network are about 378 Million euros in 2013, which 179 Million is invested in water treatment facilities and 52 Million in sewage treatment facilities. (Ympäristöhallinto, 2015) From report of Laitinen and Kallio (2016) can be estimated that about 40 percent of investments is to new equipment and networks, so rest can be calculated to be in maintenance activities, which would give an annual maintenance investment of 140 Million euros of maintenance investment in water treatment facilities.

All individual parts of older estimate are not specified in sources, but the known estimates are shown in Table 6. Maintenance in the building stock have grown noticeably from earlier estimate and this seems logical as large parts of Finnish housing stock is built in the 1970s and the building stock has aged noticeably. Also, amount of maintenance in Road and most likely rail infrastructure have returned by 2016 to same levels as in early 2000s. Estimates in rest of the infrastructure are harder to compare, but earlier estimates for these costs is noticeably larger. Most likely maintenance in infrastructure has not lowered this drastically and limitations of model and sources have caused most of the difference. Also, previous estimate includes maintenance in communications network, which is not included in the new estimate.

Table 6 Comparisons between earlier and new estimates

	Estimate of Kunnossapitoyhdistys (2003)	**Modelled estimates**
Building stock	5,5 Billion	7,6 Billion
Road network	500 Million	518 Million
Other parts of infrastructure	5,7 Billion	1,6 Billion

4.4 Future predictions in infrastructure

Total amount of maintenance without maintenance of the housing stock has grown relatively steadily over the past years and it will continue to grow slightly in the future years. In Figure 16 an estimate for future maintenance costs is shown. The total amount is estimated to be about 2,1 Billion euros in 2018. Confidence interval of 90 percent shows a low end of 2,0 Billion euros and High end of 2,3 Billion euros. The trend extended to 2020 shows were slow growth as growth of maintenance in most parts of infrastructure is not expected to be noticeable, except for electricity production.

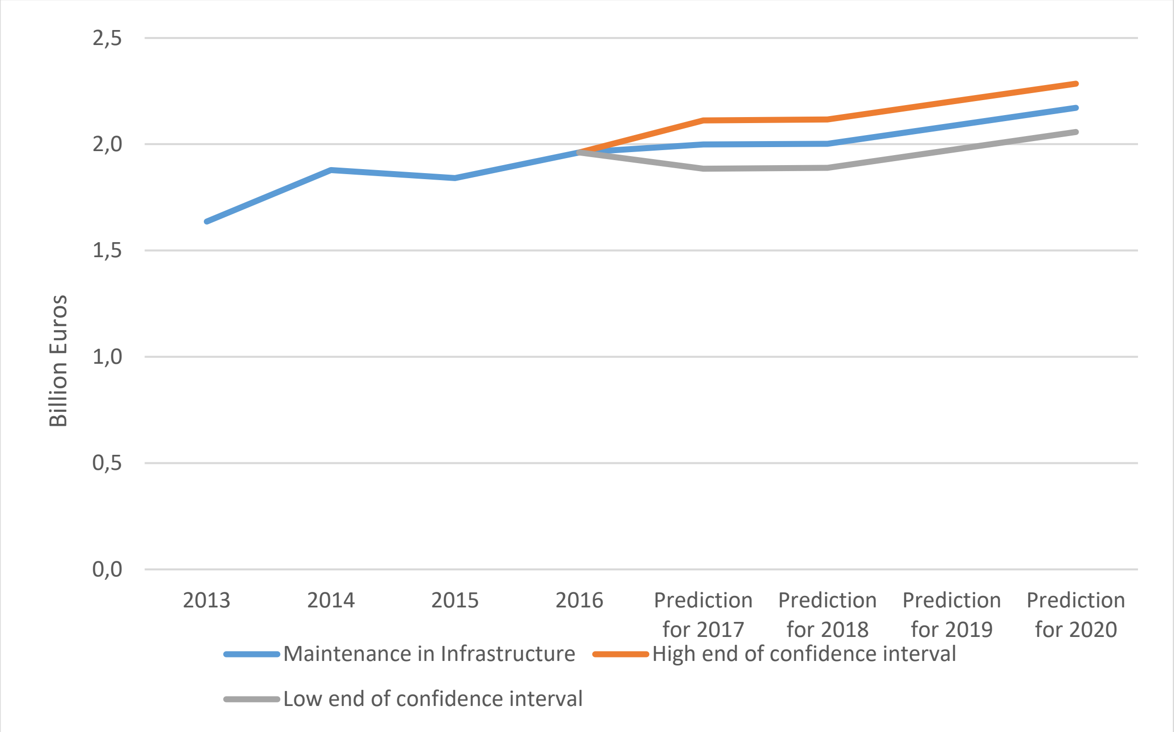

Figure 16 Maintenance cost predictions in infrastructure

Department of transportation has made budget estimates to year 2018. These estimates are used for maintenance costs of transportation network. The trend of growth in maintenance budget almost completely stops for the rest of the budgeting period. As maintenance costs in this part of infrastructure have caused the majority of growth during the modelling period the growth of maintenance costs in infrastructure can be seen to stop growing almost completely.

Predicting future energy use is hard as multiple factors affect energy demand and supply. For example, colder and longer winters will grow demand for electricity and heating, while there are multiple factors like amount of rain or fuel prices, that effect which ways power will be generated.

Largest single disruption in this part of the model will be starting of electricity production in Olkiluoto 3 nuclear reactor in 2019. This single reactor has a name plate capacity of 1600 MW, which will change noticeably the electricity production in Finland. (Teollisuuden Voima, 2018) This new reactor might force some older plants to be shut down, but more likely, as there is a notable gap between domestic electricity production and demand, domestic electricity production will grow, and the amount of imported electricity will lower (Talouselämä, 2017). This growth of electricity production will also grow the amount of maintenance done in the infrastructure in future and maintenance of this new plant will be the largest single change in maintenance of infrastructure.

Amount of district and industrial heating has grown during the modelling period and most likely will continue as there will be more investment in district heating. There are new investments in forest industries, which are the largest users of industrial heating and produce notable parts of district heating.

In transportation grid Fingrid has a planned to minimize maintenance costs in future and they are planning to change from prominently predetermined maintenance to predictive maintenance (Fingrid 2017b). During the next few years maintenance costs are likely to stay around the same level as currently. For example, it is known, that maintenance contracts for outsourced maintenance, worth over 30 million euros, have been made already for 2018-2020 (Fingrid, 2017a)

Large investment in cabling of distribution grid should lower maintenance costs in future, as lines do not have to be cleared from trees. Also, weather conditions will not cause faults in underground lines and there does not have to be as large on call maintenance force. Still large share of distribution network is on ground and maintenance costs will not lower noticeably in few next years. (Energiavirasto, 2015, p. 43)

In the future maintenance costs in district heating network will continue to grow. The network is generally expected to continue growing and older parts of network will come to the end of their life and they will need replacement.

Maintenance funding for water treatment and sewage networks has been low for many years compared to its size and maintenance backlog has grown noticeably. Laitinen & Kallio (2016) estimate, that between 2020-2030 maintenance costs in water treatment network should be 250 million euros, instead of current 120 million. Generally, need for extra funding has been a known fact and for future extra 10 million is estimated for annual growth of maintenance funding for this part of the infrastructure.

In Figure 17 estimate on amount of maintenance in building stock is shown. Lehto & Lähdemäki (2016) have estimated growth of maintenance building and this estimate is used with statistics of earlier years and future growth is 5 percent in 2017 and 2,6 percent in 2018. These estimates with confidence interval show slight growth during next few years, while lower end of estimate show dip in amount of maintenance.

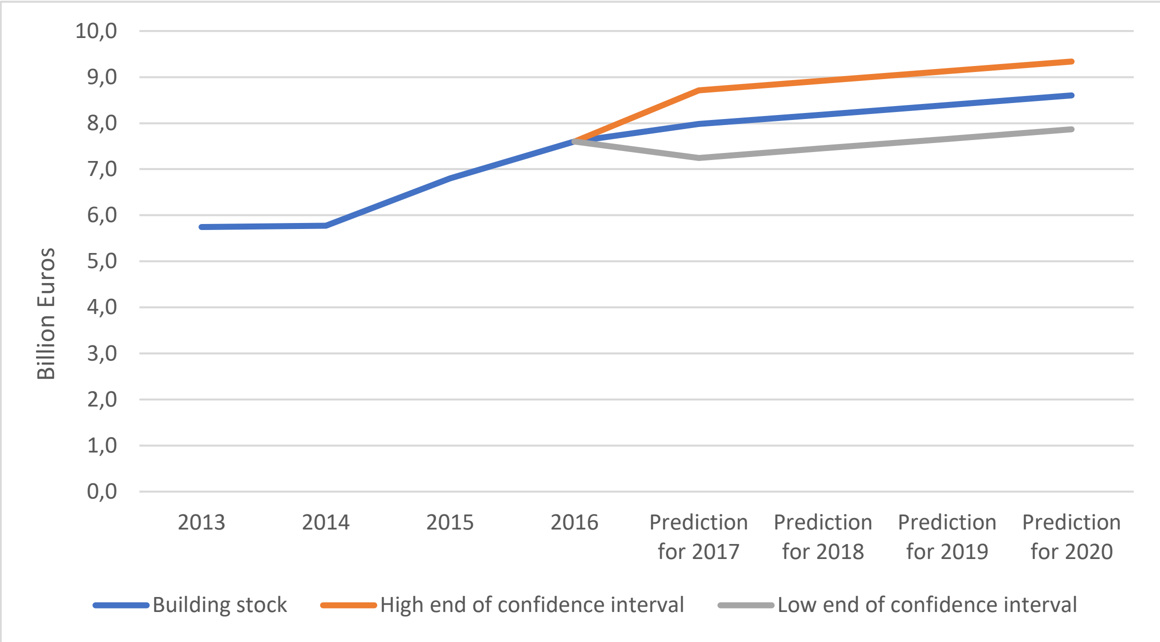

Figure 17 Maintenance cost predictions in building stock

5 MAINTENANCE EXPORT MARKET

5.1 Analysis on export market

The model for the Finnish maintenance export markets gives an estimate of market size to be around 12 Billion euros. In Figure 18 trends for this part of market can be seen and in Appendix 5 numbers for each company can be found. The market has had a growing trend in past years, but between years 2015 and 2016 there was a small drop in the market. This drop can be explained by few individual companies having a noticeable drop in their maintenance export sales, while most companies didn't have as fast growth as in earlier years.

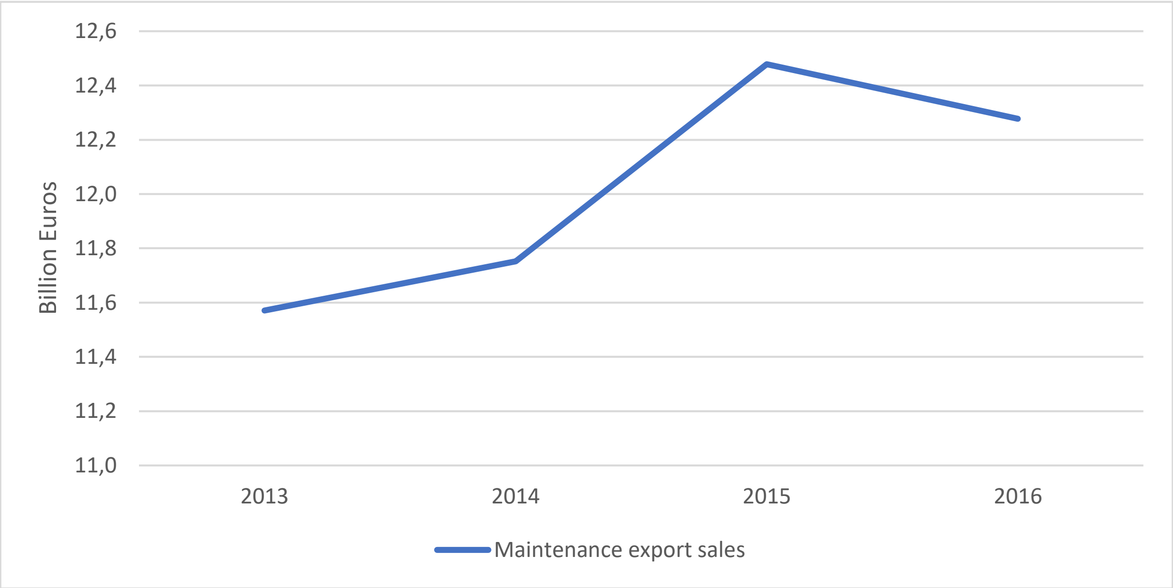

Figure 18 Finnish maintenance export sales

Finnish Customs and Statistics Finland (2017) have estimated, that entire Finnish economy had 77,1 Billion euros of exports in 2015, which of 55,4 Billion euros came from industry. Entire service exports were estimated to be 23,3 Billion euros and 10 Billion euros of this came from industries. Exports from small and medium-sized enterprises (SMEs) count to 10,1 Billion euros, which is 13 percent of Finnish exports. As model includes only large companies some maintenance exports from SMEs will be missing from the estimate.

From the model, there is an estimate of 12,5 Billion euros of maintenance export sales for the year 2015. Comparing this estimate to customs estimate of 23,3 Million for service exports, would mean that more than half of service exports would come from maintenance. This comparison is not realistic as noticeable parts of maintenance is included in product exports, as it is unknown how much spare parts or maintenance contracts are included in the sale of new machinery and products (Rautaporras, 2016).

From the results of the model it can be estimated that up to 17 percent of all Finnish exports are related to maintenance, by being maintenance services or spare part sales. This is a notable and important part of the Finnish economy and the growth of maintenance exports can be explained mostly by servitization of product-oriented companies.

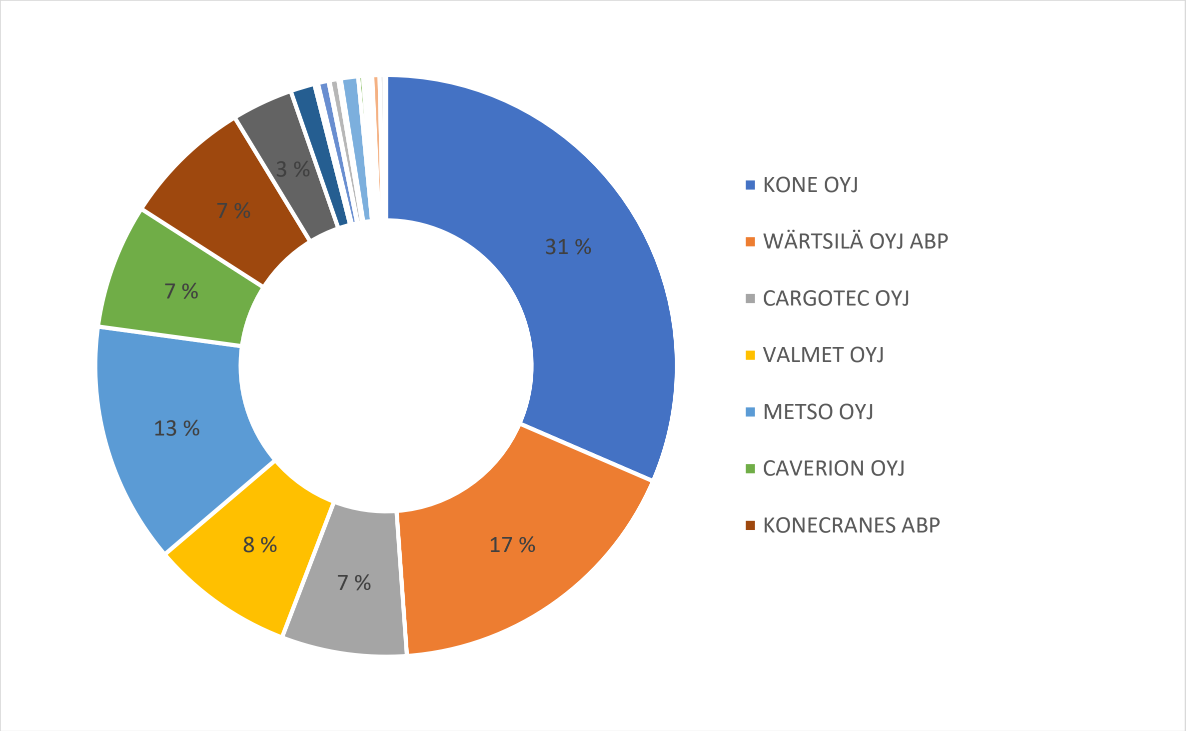

Figure 19 Market share of largest companies in 2016

The maintenance export market has few companies that make most of the market. Largest companies and their market share are shown in Figure 19. The company with largest share of maintenance exports is Kone and it counts almost to one third of the entire estimated market. Kone is one of the largest elevator and escalator companies globally and business strategy of Kone embodies the service-product system perfectly, as they aim to provide support for the whole life cycle of their products. 55 percent of Kone's sales come from new product sales while rest come from services, which include maintenance and modernisation. Kone see their future markets positively globally and the service markets are seen more positively than new product sales. (Kone, 2017)

Kone has had a strong steady maintenance sales growth for past four years and most likely will continue as it has. This and trends for other five companies with largest maintenance sales can be found in Figure 20. The company with second largest maintenance sales was Wärtsilä and trend in the past four years for them has been positive. Product sales haven't been as positive for Wärtsilä as service sales. Wärtsilä sees maintenance services as base for steady and profitable future growth. (Wärtsilä, 2017)

Metso is the third largest company in the model by estimated export sales and they are the only one of the largest product-service companies with a noticeable negative trend in maintenance export sales. They have also had an even larger dip in their product sales and service side has kept them somewhat afloat. Metso has been one of the first companies publish their annual report for 2017 and they have somewhat recovered and turned their trend to positive in 2017. (Metso, 2017; Metso, 2018)

Rest of the largest companies, as can be seen in Figure 20, haven't had large swings in their annual sales. Both Valmet and Cargotec have had marginally positive trends in maintenance export sales from 2013 to 2016. Traditional service company Caverion has had a negative trend in their maintenance export sales and they have had some issues with sales of their services, which has caused the company to start savings-program in late 2017 to streamline processes and to better profitability (Caverion, 2018, p. 5).

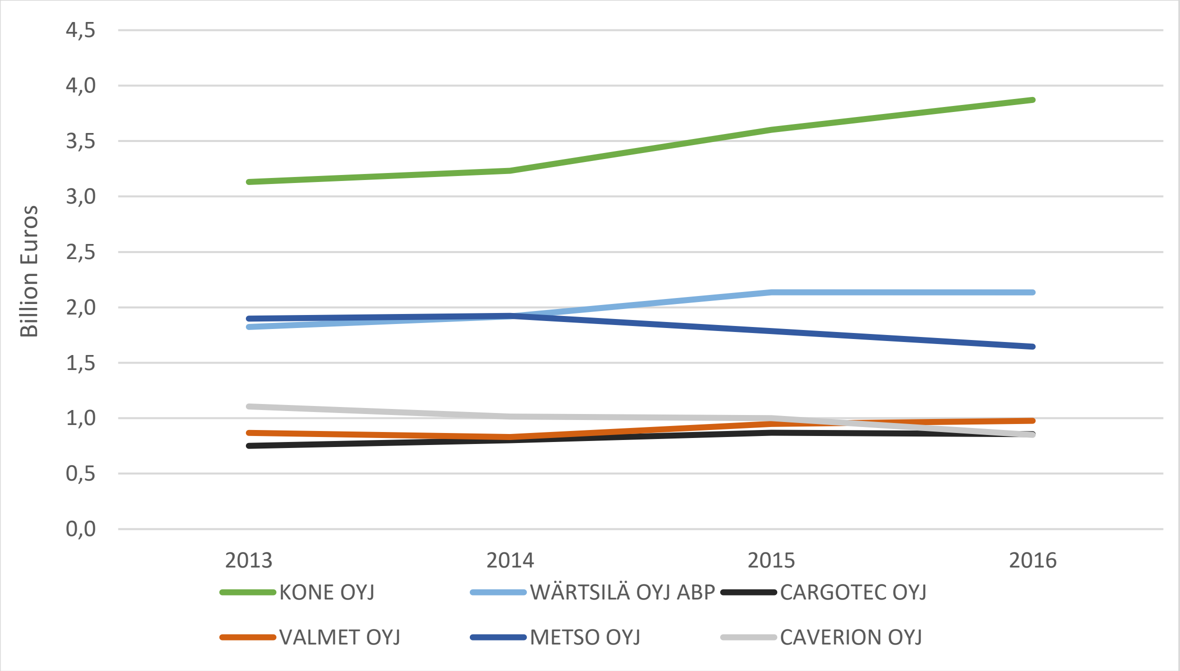

Figure 20 Trends for largest companies

5.2 Future predictions on export markets

In Figure 21 there is shown a simple prediction from average growth of past four years extended to next two years. Prediction is based on the average growth of past years, which is 284,6 Million euros annually. On this prediction a confidential interval is calculated with 90 percent confidence. From this prediction one can see that, if the trend continues as it has earlier maintenance export markets would be between 12,5 and 13,2 billion euros by year 2018. This trendline cannot be used as an accurate estimate, as it is based just on the average growth of last few years and not in any predictive data. Still the prediction shows a possible overall trend for the few future years.

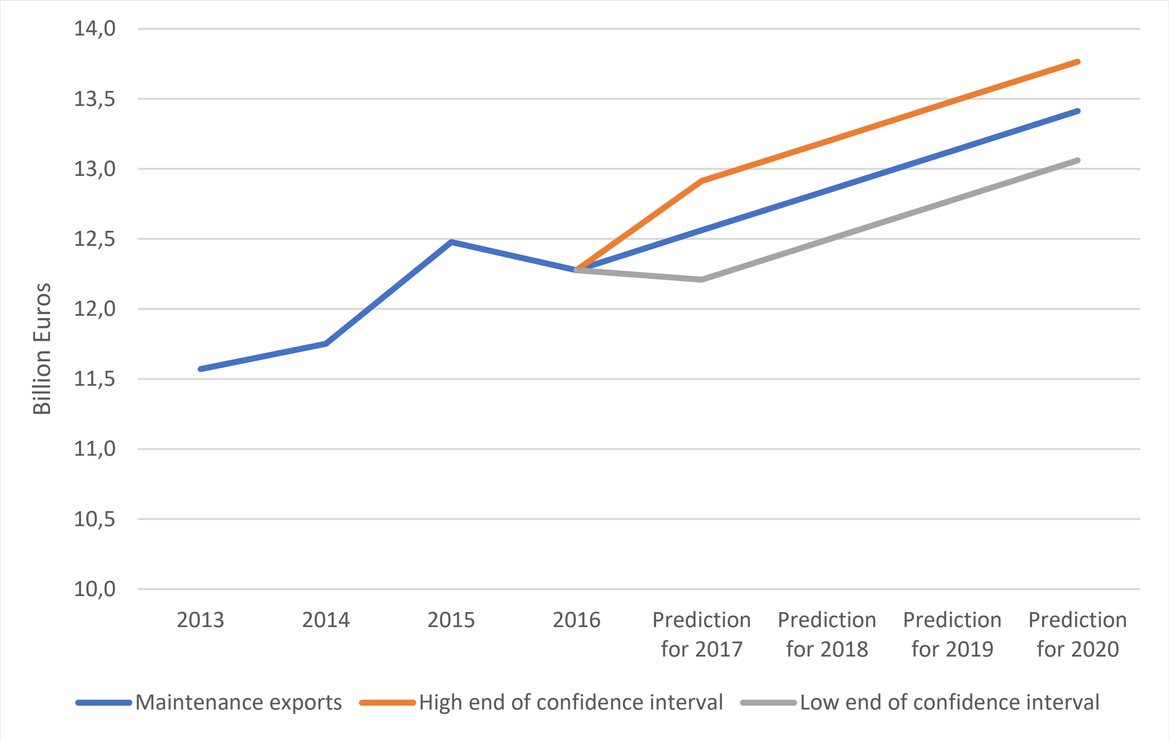

Figure 21 Predictions in maintenance exports

There should not be limitations for growth reached in near future, as the global maintenance market will grow in the future, especially in growth will be in predictive maintenance (Business wire, 2017). Largest limitations for market growth come from limitations for single companies, as for example Konecranes (2017, p. 3) already has the largest market share in crane maintenance and Wärtsilä (2018, p. 20) provides maintenance for only their own products, which limits the possible growth. Possible trend for insourcing might limit growth of maintenance service exports, but on the other hand growth of predictive maintenance and complexity of new maintenance methods might require more external services (Torttila, 1994, p. 70; Deierlein, 1998; Salo, 2015)

Most of the largest companies estimate future maintenance sales positively, as can be seen from Table 7. As only few of the companies at the time of writing had published their annual reports for year 2017 the year cannot be taken as the primary year for model. Still the newest annual data is used when predicting future markets.

Table 7 Predictions for maintenance exports of the largest companies

Company:	Their prediction:
Kone	Overall expectations of growth in maintenance sales
Wärtsilä	Maintenance sales small and stable growth, limitation of maintenance sales being offered primarily on their own products.
Metso	Realised growth in service sales in 2017 and expected in future
Valmet	Realised growth in service sales in 2017 and expected in future
Cargotec	Small growth in 2017, no large growth expectation for 2018
Caverion	Lowering trend expected to continue in future years
Konecranes	Possibilities for growth through recent acquisitions

Most large companies discuss the future of maintenance through digitalisation and maintenance services provided through IoT. Cargotec has tested and commercialised their first digital maintenance services in 2017 (Cargotec, 2018). Wärtsilä expects next disruption in maintenance market to come from digitalization (Wärtsilä, 2018).

Most of the largest companies in the model expect positive market growth in global industrial markets. Even though many companies like Valmet expect investments in new equipment to lower, they expect that at the same time maintenance sales are going to grow. This growth of maintenance sales is especially expected to come from production equipment in Asia as a lot of equipment there is becoming older. The need for modernisation of this production equipment is becoming more relevant as the equipment ages (Valmet, 2018).

Caverion has named their savings-program as “Fit for growth” and it can be divided to two faces of “fit” and “for growth”. First, the “fit”, face of Caverion’s savings program will end by 2019 and during this face Caverion expects future sales to continue declining. On the second face from 2019 to 2020 they expect to be ready for growth. Even while Caverion has their savings-program, they will focus on four future megatrends in building and maintenance services, which are digitalisation, increase in technology, energy efficiency and urbanisation. (Caverion, 2018, p. 7)

Digitalization and smartification of maintenance causes some issues in predicting changes in maintenance markets future. As any other disruptive innovations digitalization of maintenance could and most likely will disturb market positions of current companies and will force current and new companies to change their offering. These disruptive changes are hard to predict, but it seems that most companies are preparing for them.

Digitalization is also seen as a requirement for growth of predictive maintenance, which would allow smarter and more effective maintenance management. This would allow service provider to increase amount of sales per maintenance worker, which would grow maintenance sales without expanding the company. Overall it seems that maintenance markets will continue to grow in the future and maintenance will become even more important factor in the economies of multiple companies.

6 CONCLUSIONS

6.1 Results of the study

Maintenance methods have changed noticeably during past decades in industries and for example predictive maintenance and outsourcing of maintenance have been used more to optimize maintenance costs. This change in methods has lowered share of maintenance costs of sales in industries, but at the same time Finnish industrial output has grown noticeably, which has caused overall maintenance costs to grow.

Maintenance costs in infrastructure and housing stock are also notable and maintenance backlog in this part of maintenance is also a large known factor, that lowers the realised maintenance costs compared to costs, that are needed to keep infrastructure in excellent working condition. Still the condition of vital infrastructure is overall on an acceptable level except for few parts like water treatment.

Maintenance export markets have become extremely relevant in past decades as service exports have become easier through international treaties and digitalisation of services. This growth has also been facilitated by the trend of servitization of production companies, which has made maintenance service exports large and profitable parts of many companies' offerings. Next in this chapter answers to the research questions are explored. After which prospects for additional research are pondered on. There were three research questions in this study.

RQ1: How can the Finnish domestic and export maintenance markets be modelled?

Modelling of maintenance markets can be done accurately through public sources. Model made in this study was divided into three different parts and all of them are analysed in the study. Maintenance in industries and mining were modelled with average maintenance costs per sales and for most industries shares of maintenance costs could be found. Maintenance cost data can be found especially for largest industries and averages can be estimated. Average of three percent of sales was used for industries where maintenance costs were unknown, this average was chosen as it was slightly lower than estimates in earlier research, which was a trend consistently found in answers for maintenance averages. Results of the model react fast to price changes and changes in sales amounts, which might be faster than in real life, but especially when sales stagnate, cutting maintenance work is an easy way to reduce costs.

Modelling in Infrastructure is mostly based on public sources and budgets, this means that some privately-owned parts might be missing from the model. Parts of vital infrastructure were modelled trough other sources and calculations, which might limit the overall accuracy of the model, but these choices allow estimate to cover infrastructure more widely. Also missing parts from model are known, which makes expanding model later easier. As an example, maintenance in nonindustrial harbours is missing from the model and maintenance done to street network on a municipal level is not included in the model, but these missing parts should not be noticeably large compared to the modelled parts, so they do not compromise the accuracy of the model.

Model for exports is done through largest Finnish companies. Modelled companies were chosen from 501 largest Finnish companies and two companies outside the list were added as they had notable exports. From these companies a list of the most important maintenance exporters is gathered, and their sales are analysed to find maintenance export sales. After few largest companies, maintenance exports lower noticeably and smaller companies contribute less to the entire market, which means that missing smallest companies does not compromise the accuracy of the model.

RQ2: What are the results from these models?

Results from the model are shown in Table 8. Entire domestic maintenance market is about 13,6 Billion euros and maintenance export sales are about 12,3 Billion euros. Different parts of the market had their own consistent trends during the modelling period. Industrial maintenance had a stable, but slightly negative trend and maintenance market in industry lowered from 4,3 to 4,1 Billion euros, while infrastructural market grew from 1,7 to 2,1 Billion euros and maintenance in building stock had extremely positive trend of 5,7 to 7,6 Billion. Export market also grew from 11,6 to 12,3 Billion euros with a peak in 2015 of 12,5 Billion.

Table 8 Results of modelling

Market	**Size in 2016 (Billion Euros)**
Domestic industrial market	4,1
Domestic infrastructural market	2,1
Maintenance in building stock	7,6
Export market	12,3
Entire market	26,1

Accurate estimate on amount of maintenance industry employees is harder to make, as this number must be sourced from multiple sources and maintenance employees are counted differently in different companies. The overall number of employees has lowered in industry and out of 300 thousand industrial personnel most likely around 40 to 60 thousand persons working primarily in industrial maintenance. About 10 thousand of these persons are employed by service providers.

Maintenance methods in Finnish industrial maintenance have changed during recent years and electrical and automation maintenance are more relevant than in earlier Finnish research. Also, as number of employees has lowered while market has grown has maintenance work become noticeably more efficient and optimised.

In these estimates there are no infrastructural maintenance workers or workers working in building maintenance and these fields include large worker counts. Also, there is no estimate made on number of workers working with maintenance exports as large part of these sales are done abroad by local workers.

RQ3: What are the trends in maintenance market in the future?

The major future trends for maintenance market found from literature and questionnaire include for example growth of preventive and predictive maintenance, which is made possible by maturation of IoT. Also, issues like loss of tacit knowledge and lack of training of maintenance personnel. For some trends there was no consensus found and the most notable of these is the possibility of growth of outsourcing or insourcing. Some sources and answerers argue, that trend of outsourcing would turn around to allow companies to assume more control. On the other hand, some sources expect to trend of outsourcing to continue as maintenance and production methods are expected to continue to become more complicated. This higher complexity means that maintenance personnel need specialist knowledge which makes outsourcing a better option than inhouse maintenance.

Changes of maintenance market are calculated for next two years and after these trends are extended to 2020. Industrial market is expected to grow by two percent on average between 2016 and 2020. This growth comes from growth of sales in most but not all individual industries. Growth of maintenance in infrastructure can be expected to stagnate for few years after which electricity maintenance costs will grow through new capacity. Meanwhile maintenance in housing stock will continue growing by three percent annually. Some parts of infrastructure need higher maintenance budgets and spending to make sure that infrastructure stays in working condition, which means that maintenance costs should grow in future in these parts of infrastructure, but timeframe of this growth is most likely outside the modelled period. Maintenance exports are generally expected to grow as largest companies working with maintenance service exports expect their sales to continue growing and average growth of two percent.

6.2 Suggestions on future research

This study has some limitations and does not give conclusive answers on all aspects of the maintenance markets and more research must be done on the topic. Research on maintenance backlog in industries would be important subject to study as it most likely has a similar limiting function as maintenance backlog in Infrastructure.

In this study a general trend of lowering maintenance costs per sales was found. Research on the real reasons behind lowering of maintenance indicators could be a possible topic for future research. Also, there is a need to find average indicators for industries that are estimated with overall average indicators and accuracy of currently estimated indicators should be confirmed. This updating of the maintenance costs indicators is extremely important for continued use of model made in this study.

Other parts of maintenance market need more research too, like estimates on amount of outsourced domestic maintenance should be done. This means improving estimates by estimating sales of outsourced maintenance through different industries like group 33. Also, estimates on maintenance on parts outside the model, like communications network and maintenance exports sales of SMEs

More accurate estimates on number of maintenance employees should be done. Current estimate on industrial maintenance personnel is decent but estimating number of employees through individual industries would give more accurate results. Number of employees in maintenance of infrastructure and number of persons working with maintenance exports are currently unknown and estimating amounts of these employees would be also an interesting topic for research.

7 SUMMARY

As can be seen in the study the size of maintenance market is notable and it is composed of multiple different types of activities and offerings. Modelled results show that in 2016 the domestic Finnish industrial maintenance market was about 4,1 billion euros and it employed 40 to 60 thousand primary maintenance personnel. Size of maintenance in infrastructure and building stock was about 9,7 Billion euros and size of maintenance export market was about 12,3 billion euros.

Primary objective of this study was to produce an updatable model and analyse size and development of Finnish maintenance markets. As a result of this study models on maintenance costs and development of these costs in domestic Finnish industrial maintenance markets, Finnish infrastructural market and on Finnish maintenance export service markets were made. To support modelling and analysis a questionnaire was done in which questions on amounts of industrial primary maintenance workers and changes in industrial maintenance methods were asked and these answers were analysed. Forecasts were made on possible changes during the next few years in all modelled markets.

The results shown in this study are not conclusive and more research on many parts of the study should be done, for example the reasons behind lowered maintenance costs per turnover should be analysed and more accurate estimates on amounts of maintenance personnel should be done. Regardless of its inaccuracies, this study provides a quite accurate estimates of the maintenance market size. Also, as the primary objective of this study was to make an updatable model, that provides an overall vision on the size and development of different maintenance sectors, this reached accuracy on modelled results is acceptable. Additionally, this study provides latest information on the development of the Finnish maintenance market and predicts future changes both numerically for few next years and with more general trends on a longer time scale.

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APPENDIX 1, Questions of the questionnaire (1/2)

Yleiset kysymykset

1. Vastaajan rooli yrityksessä
    a. Ylin johto
    b. Keskijohto (kunnossapitopäällikkö, tehdaspalvelupäällikkö, vastaava)
    c. Muu, mikä?
2. Arvioinnin kohde
    a. Koko yritys
    b. Yksittäinen tuotantoyksikkö tai toimipaikka
3. Yrityksen toimiala
    a. lista eri toimialoista TOL2008 mukaan
4. Yrityksen tai tuotantoyksikön liikevaihto
5. Yrityksen tai tuotantoyksikön henkilöstömäärä
6. Yrityksen rooli kunnossapidossa
    a. Kunnossapidon asiakas
    b. Palvelun tarjoaja
    c. Sekä asiakas, että kunnossapitopalvelun tarjoaja omille tuotteille

Kunnossapidon asiakkaat (mikäli vastasitte kohtaan 7 a taikka c)

7. Arvio yrityksen tai tuotantolaitoksen vuosittaisista kunnossapitokustannuksista suhteessa liikevaihtoon? (prosentteina)
8. Arvio yrityksen tai tuotantolaitoksen vuosittaisista kunnossapitokustannuksista suhteessa tuotantolaitteiden jälleenhankinta-arvoon? (prosentteina)
9. Arvio yrityksen tai tuotantoyksikön kustannuksista verrattuna toimialaan
    a. Toimialaan verrattuna suuremmat kunnossapitokustannukset
    b. Toimialaan verrattuna normaalit kustannukset
    c. Toimialaan verrattuna pienemmät kustannukset
10. Ensisijaisten kunnossapitohenkilöiden osuus koko yrityksen tai tuotantoyksikön työntekijöistä? (prosentteina)
11. Kunnossapitohenkilöstön jakautuminen kunnossapitolajien kesken? (prosentteina)
    a. Mekaaninen kunnossapito
    b. Sähkö- ja automaatiokunnossapito
    c. Muu kunnossapitohenkilöstö mukaan lukien kunnossapidon johto
12. Yrityksen tai tuotantoyksikön kunnossapidon toteuttamisstrategia?
    a. Toteutetaan pääsääntöisesti omana kunnossapitona
    b. Toteutetaan osittain omana kunnossapitona ja osittain ulkoistettu
    c. Ulkoistettu kokonaan
13. Ulkoisien toimittajien lukumäärä?
    a. Ei ulkopuolisia toimittajia
    b. Yksi ulkopuolinen toimittaja
    c. Useita ulkopuolisia toimittajia
14. Kunnossapitokustannusten jakautuminen eri toimijoiden kesken
    a. Oman työn osuus kunnossapidon kokonaiskustannuksista
    b. Ulkoistetun kunnossapidon osuus kunnossapidon kokonaiskustannuksista
    c. Materiaalien osuus kunnossapidon kokonaiskustannuksista

APPENDIX 1, Questions of the questionnaire (2/2)

15. Miten kunnossapitotyöt jakautuvat?
    a. Korjaavan kunnossapidon osuus tehdyistä kunnossapidon kustannuksista
    b. Ennakoidun kunnossapidon osuus tehdyistä kunnossapidon kustannuksista
16. Miten kunnossapito tulee muuttumaan tulevaisuudessa, mitkä ovat mielestäsi keskeisiä muutoksia mahdollisuuksia ja uhkia kunnossapidossa?

Kunnossapidon toimittajat (mikäli vastasitte kohtaan 7 b tai c):

17. Kunnossapitohenkilöstön jakautuminen eri toimintojen kesken? (prosentteina)
    a. Mekaaninen
    b. Sähkö- ja automaatio
    c. Muu kunnossapitohenkilöstö mukaan lukien kunnossapidon johto
18. Avainasiakkaiden (yli 10 % yksikön tai yrityksen liikevaihdosta samalta asiakkaalta) määrä?
    a. Ei avainasiakkaita
    b. Yksi avainasiakas
    c. Useita avainasiakkaita
19. Kuinka suuri osa avainasiakkaiden kunnossapidosta toteutetaan toimittajan toimesta?
20. Tarjotut kunnossapidon palvelut?
    a. Korjaavan kunnossapidon osuus toimitetuista kunnossapidon töistä
    b. Ennakoidun kunnossapidon osuus toimitetuista kunnossapidon töistä
21. Miten kunnossapito tulee muuttumaan tulevaisuudessa, mitkä ovat mielestäsi keskeisiä muutoksia mahdollisuuksia ja uhkia kunnossapidossa?

APPENDIX 2, Maintenance in industries (1/2)

Industry:	2013 Sales (Million €)	2014 Sales (Million €)	2015 Sales (Million €)	2016 Sales (Million €)	Estimate	Maintenance costs 2013 (Million €)	Maintenance costs 2014 (Million €)	Maintenance costs 2015 (Million €)	Maintenance costs 2016 (Million €)
B Mining and quarrying	1 730	1 661	1 501	1 487	**6,9 %**	119	115	104	103
10 Manufacture of food products	10 022	10 022	9 762	9 484	**2,5 %**	251	251	244	237
11 Manufacture of beverages	1 261	1 132	1 174	1 230	**3,0 %**	38	34	35	37
12 Manufacture of tobacco products	-	-	-	-	**3,0 %**	-	-	-	-
13 Manufacture of textiles	484	463	375	394	**3,0 %**	15	14	11	12
14 Manufacture of wearing apparel	650	637	607	622	**3,0 %**	19	19	18	19
15 Manufacture of leather and related products	244	227	216	223	**3,0 %**	7	7	6	7
16 Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	6 357	6 360	6 208	6 452	**4,4 %**	280	280	273	284
17 Manufacture of paper and paper products	19 341	19 051	19 277	20 874	**4,0 %**	774	762	771	835
18 Printing and reproduction of recorded media	1 356	1 218	1 133	1 077	**3,0 %**	41	37	34	32
19 Manufacture of coke and refined petroleum products	11 981	10 356	6 534	6 546	**3,0 %**	359	311	196	196
20 Manufacture of chemicals and chemical products	7 827	7 749	7 946	7 686	**4,0 %**	313	310	318	307
21 Manufacture of basic pharmaceutical products and pharmaceutical preparations	1 689	1 863	1 911	2 164	**3,5 %**	59	65	67	76
22 Manufacture of rubber and plastic products	3 196	3 269	3 252	3 262	**4,0 %**	128	131	130	130

APPENDIX 2, Maintenance in industries (2/2)

Industry:	**2013 Sales (Million €)**	**2014 Sales (Million €)**	**2015 Sales (Million €)**	**2016 Sales (Million €)**	**Estimate**	**Maintenance costs 2013 (Million €)**	**Maintenance costs 2014 (Million €)**	**Maintenance costs 2015 (Million €)**	**Maintenance costs 2016 (Million €)**
23 Manufacture of other non-metallic mineral products	3 174	3 082	3 030	2 975	**5,8 %**	185	179	176	173
24 Manufacture of basic metals	7 495	8 840	11 926	10 885	**5,0 %**	375	442	596	544
25 Manufacture of fabricated metal products, except machinery and equipment	6 674	6 424	6 575	6 736	**2,3 %**	154	148	151	155
26 Manufacture of computer, electronic and optical products	25 967	22 629	16 043	12 689	**2,3 %**	597	520	369	292
27 Manufacture of electrical equipment	4 864	5 038	5 233	5 111	**2,3 %**	112	116	120	118
28 Manufacture of machinery and equipment.	15 281	15 158	15 701	15 427	**2,3 %**	351	349	361	355
29 Manufacture of motor vehicles, trailers and semi-trailers	1 442	1 488	1 631	1 679	**3,0 %**	43	45	49	50
30 Manufacture of other transport equipment	1 730	1 583	1 584	1 955	**3,0 %**	52	47	48	59
31 Manufacture of furniture	1 066	1 026	1 046	1 090	**3,0 %**	32	31	31	33
32 Other manufacturing	705	642	675	668	**3,0 %**	21	19	20	20
SUM:	136 685	131 946	125 833	123 280	-	4 325	4 230	4 130	4 073

APPENDIX 3, Prediction for maintenance in industries (1/2)

Industry	**Predicted change 2017 (Lehto & Lähdemäki, 2016)**	**Predicted change 2018. (Lehto & Lähdemäki, 2016)**	**Predicted sales 2017 (Million €)**	**Predicted sales 2018 (Million €)**	**Predicted maintenance costs 2017 (Million €)**	**Predicted maintenance costs 2018 (Million €)**
B Mining and quarrying	0,0 %	0,0 %	1 487	1 487	103	103
10 Manufacture of food products	0,0 %	0,0 %	9 484	9 484	237	237
11 Manufacture of beverages	0,0 %	0,0 %	1 230	1 230	37	37
12 Manufacture of tobacco products	0,0 %	0,0 %	-	-	-	-
13 Manufacture of textiles	-5,3 %	-4,9 %	373	355	11	11
14 Manufacture of wearing apparel	-5,3 %	-4,9 %	589	560	18	17
15 Manufacture of leather and related products	-5,3 %	-4,9 %	211	201	6	6
16 Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	4,9 %	-1,0 %	6 768	6 701	298	295
17 Manufacture of paper and paper products	2,2 %	2,1 %	21 333	21 781	853	871
18 Printing and reproduction of recorded media	-2,6 %	-4,4 %	1 049	1 003	31	30
19 Manufacture of coke and refined petroleum products	-2,7 %	-3,3 %	6 370	6 159	191	185
20 Manufacture of chemicals and chemical products	1,8 %	2,4 %	7 825	8 012	313	320
21 Manufacture of basic pharmaceutical products and pharmaceutical preparations	5,8 %	12,0 %	2 290	2 565	80	90
22 Manufacture of rubber and plastic products	3,4 %	2,0 %	3 373	3 441	135	138

APPENDIX 3, Prediction for maintenance in industries (2/2)

Industry	**Predicted change 2017 (Lehto & Lähdemäki, 2016)**	**Predicted change 2018 (Lehto & Lähdemäki, 2016)**	**Predicted sales 2017 (Million €)**	**Predicted sales 2018 (Million €)**	**Predicted maintenance costs 2017 (Million €)**	**Predicted maintenance costs 2018 (Million €)**
23 Manufacture of other non-metallic mineral products	2,7 %	2,1 %	3 055	3 119	178	182
24 Manufacture of basic metals	3,0 %	2,2 %	11 212	11 459	561	573
25 Manufacture of fabricated metal products, except machinery and equipment	3,7 %	2,9 %	6 985	7 187	161	165
26 Manufacture of computer, electronic and optical products	2,0 %	2,3 %	12 943	13 241	298	305
27 Manufacture of electrical equipment	2,6 %	3,4 %	5 244	5 422	121	125
28 Manufacture of machinery and equipment.	1,4 %	3,8 %	15 643	16 237	360	373
29 Manufacture of motor vehicles, trailers and semi-trailers	25,1 %	1,6 %	2 101	2 134	63	64
30 Manufacture of other transport equipment	3,9 %	18,0 %	2 031	2 397	61	72
31 Manufacture of furniture	0,0 %	0,0 %	1 090	1 090	33	33
32 Other manufacturing	0,0 %	0,0 %	668	668	20	20
SUM:			123 353	125 932	4 167	4 250

APPENDIX 4, Maintenance in infrastructure

	Maintenance costs 2013 (Million €)	Maintenance costs 2014 (Million €)	Maintenance costs 2015 (Million €)	Maintenance costs 2016 (Million €)	Predicted maintenance costs 2017 (Million €)	Predicted maintenance costs 2018 (Million €)
Transportation networks	612	879	851	947	973	967
Road network	421	473	453	518	524	508
Rail network	170	328	320	345	361	373
Water ways	21	78	79	83	89	86
Electric grid	69	69	74	75	75	75
District heating grid	18	19	19	19	20	20
Electricity production	496	476	481	484	484	484
Heat production	282	284	280	311	311	311
Water treatment	260	260	260	260	270	280
Building stock	5 745	5 771	6 800	7 600	7 980	8 187
SUM:	7 482	7 758	8 765	9 696	10 113	10 325
SUM without building stock	1 737	1 987	1 965	2 096	2 133	2 137

APPENDIX 5, Maintenance export sales (1/3)

Company name		2013	2014	2015	2016
KONE OYJ	**Maintenance sales**	3 188 996 000	3 300 525 000	3 713 000 000	3 991 000 000
	Share of exports	98,2 %	97,9 %	97,0 %	97,0 %
	Maintenance exports	3 131 174 000	3 232 125 000	3 601 610 000	3 871 270 000
WÄRTSILÄ OYJ ABP	**Maintenance sales**	1 842 000 000	1 939 000 000	2 184 000 000	2 190 000 000
	Share of exports	99,0 %	98,9 %	97,8 %	97,5 %
	Maintenance exports	1 823 580 000	1 917 671 000	2 135 952 000	2 135 250 000
CARGOTEC OYJ	**Maintenance sales**	763 000 000	814 400 000	882 700 000	872 200 000
	Share of exports	98,4 %	98,5 %	98,5 %	98,2 %
	Maintenance exports	751 030 902	802 103 234	869 397 841	856 735 373
VALMET OYJ	**Maintenance sales**	1 032 000 000	989 000 000	1 128 000 000	1 163 000 000
	Share of exports	84 %	84 %	84 %	84 %
	Maintenance exports	866 880 000	830 760 000	947 520 000	976 920 000
METSO OYJ	**Maintenance sales**	1 976 000 000	2 007 000 000	1 840 000 000	1 703 000 000
	Share of exports	96 %	96 %	97 %	97 %
	Maintenance exports	1 898 148 263	1 923 603 609	1 786 227 746	1 645 706 497
CAVERION OYJ	**Maintenance sales**	1 409 300 000	1 297 000 000	1 290 700 000	850 231 842
	Share of exports	78,5 %	78,4 %	77,6 %	75,2 %
	Maintenance exports	1 106 150 810	1 016 207 852	1 001 652 939	850 231 842
KONECRANES ABP	**Maintenance sales**	889 100 000	895 100 000	992 300 000	968 000 000
	Share of exports	96,5 %	96,6 %	96,4 %	91,6 %
	Maintenance exports	857 552 110	864 438 575	957 064 063	886 388 973
OUTOTEC OYJ	**Maintenance sales**	506 547 500	518 962 000	511 711 200	447 491 700
	Share of exports	99,0 %	98,6 %	98,0 %	93,4 %
	Maintenance exports	501 482 025	511 696 532	501 476 976	417 957 248

APPENDIX 5, Maintenance export sales (2/3)

Company name		2013	2014	2015	2016
ANDRITZ OY	**Maintenance sales**	161 150 000	181 537 782	243 664 400	220 772 000
	Share of exports	75 %	75 %	75 %	75 %
	Maintenance exports	120 862 500	136 153 337	182 748 300	165 579 000
PÖYRY OYJ	**Export sales**	27 100 000	26 400 000	27 200 000	24 745 000
	Share of maintenance	33 %	33 %	33 %	33 %
	Maintenance exports	8 943 000	8 712 000	8 976 000	8 165 850
PONSSE OYJ	**Maintenance sales**	65 764 000	76 595 000	84 396 000	95 086 000
	Share of exports	75,0 %	70,0 %	76,6 %	76,6 %
	Maintenance exports	49 323 000	53 616 500	64 647 336	72 835 876
SCANFIL OYJ	**Maintenance sales**	0	0	2 625 000	7 525 000
	Share of exports	0,0 %	0,0 %	82,3 %	82,3 %
	Maintenance exports	0	0	2 160 053	6 192 152
PATRIA OYJ	**Maintenance sales**	100 512 000	122 200 000	84 506 000	112 135 000
	Share of exports	54 %	50 %	49 %	54 %
	Maintenance exports	54 276 480	61 100 000	41 407 940	60 552 900
ASPO OYJ	**Maintenance sales**	26 934 270	29 150 880	25 986 840	24 774 090
	Share of exports	67,1 %	66,5 %	66,9 %	67,3 %
	Maintenance exports	18 073 048	19 371 542	17 375 291	16 682 501
ROLLS-ROYCE OY AB	**Maintenance sales**	232 754 595	226 798 258	196 775 740	131 691 370
	Share of exports	90 %	90 %	90 %	90 %
	Maintenance exports	209 479 136	204 118 433	177 098 166	118 522 233
AGCO POWER OY	**Maintenance sales**	55 501 151	42 303 458	37 633 280	43 890 720
	Share of exports	75,0 %	75,0 %	75,0 %	75,0 %
	Maintenance exports	41 625 863	31 727 594	28 224 960	32 918 040

APPENDIX 5, Maintenance export sales (3/3)

Company name		2013	2014	2015	2016
BRP FINLAND OY	**Spare parts sales**	38 597 920	43 593 440	44 489 760	40 495 360
	Share of exports	66 %	66 %	66 %	66 %
	Maintenance exports	25 474 627	28 771 670	29 363 242	26 726 938
VR TRACK OY	**Maintenance sales**	41 566 026	54 163 356	78 741 837	65 964 989
	Share of exports	25 %	25 %	25 %	25 %
	Maintenance exports	10 391 507	13 540 839	19 685 459	16 491 247
ALGOL OY	**Maintenance sales**	46 310 983	37 246 220	32 667 000	36 068 000
	Share of exports	5 %	5 %	5 %	5 %
	Maintenance exports	2 315 549	1 862 311	1 633 350	1 803 400
RAMBOLL FINLAND OY	**Maintenance sales**	6 900 000	5 500 000	5 400 000	8 806 000
	Share of exports	50 %	50 %	50 %	50 %
	Maintenance exports	3 450 000	2 750 000	2 700 000	4 403 000
NESTE ENGINEERING SOLUTIONS OY	**Export sales**	12 900 000	29 900 000	33 000 000	12 379
	Share of maintenance	33 %	33 %	33 %	33 %
	Maintenance exports	4 257 000	9 867 000	10 890 000	12 379 290
MAINTPARTNER GROUP OY	**Maintenance sales**	158 000 000	160 000 000	165 000 000	156 000 000
	Share of exports	70 %	75 %	73 %	68 %
	Maintenance exports	47 500 000	40 000 000	45 000 000	50 000 000
RAUTE OYJ	**Maintenance sales**	29 145 900	35 727 980	42 001 740	42 989 400
	Share of exports	90 %	92 %	76 %	78 %
	Maintenance exports	26 231 310	32 869 742	31 921 322	33 531 732
EMPOWER OYJ	**Export sales**	42 483 000	30 238 000	45 700 000	33 900 000
	Share of maintenance	30 %	30 %	30 %	30 %
	Maintenance exports	12 744 900	9 071 400	13 710 000	10 170 000