Master Thesis

Determining CMMS needs in an industrial group

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Abstract

Background: In order for manufacturing companies to stay competitive today, it is important to continuously strive towards eliminating any sources of waste. One of the tools to address waste elimination is to work with Total Productive Maintenance (TPM), which essentially is a structured way of improving the company's machine reliability and production effectiveness through enhancing the sites maintenance operations. To fully realise the benefits of TPM, large amounts of data has to be gathered, stored and analysed, which calls for the support from an IT-system, often referred to as a CMMS (Computerised Maintenance Management System).

The case company Trelleborg is an industrial group with more than 100 manufacturing sites of which most of them needs, or will need, the support from a CMMS in order to have efficient maintenance operations. Trelleborg recognised potential benefits of having the same CMMS in all of their manufacturing sites and wanted to investigate it.

Problem: As a CMMS is closely linked to successfully working with TPM, that implicates that it should be beneficial for an industrial group to have a standardised CMMS to ensure every plant has the tools necessary to realise the benefits of TPM. Research on the implementation of CMM-systems has shown that the benefits of the systems greatly diminish if it is not utilised properly, and in most cases low utilisation is the result of an inadequate selection process, resulting in a poor organisational fit. Consequently, choosing a CMMS to standardise in an industrial group is a challenging task with both high risk and reward.

Purpose: To develop a step-by-step procedure that can be used in order to identify the needs of a CMMS system in an industrial group.

Method: As the authors aimed to both understand what criteria that are important to consider when selecting a standardised CMMS, and to use those criteria to determine the specific needs of Trelleborg group, an abductive pragmatic approach to research was held. The study was conducted with a mixed research strategy, incorporating both an embedded, single-case study and a survey strategy. The focus was to extend the current, single-plant context, theory with the practices of an industrial group, to determine what criteria are important to consider in this context. This was done through data gathering, either by interviews or a survey, from 30 of Trelleborgs plants that had a structured approach to maintenance, which then was compared to the frame of reference. The frame of reference was created through literature studies, internal material from Trelleborg and unstructured interviews with both CMMS-suppliers and Trelleborg employees. The combination of these two acted as a foundation for the analysis and the development of the need identification process, as well as further recommendations to Trelleborg.

Conclusion: A number of factors that are important to consider in the standardisation of a CMMS in an industrial group, which can be categorised into six groups; group, plants, individuals, system, supplier and technology. This project also resulted in a need identification process designed to assist an industrial group in the evaluation of these factors in order to determine which requirements they have on a CMMS. The application of the process on Trelleborg yielded a need specification that they felt was rfelevant, and it seemed possible to find a standardised CMMS in this case.

Need identification process: The developed need identification process is a 5 step approach incorporating start-up, data gathering, need elicitation and specification. It is aimed towards both ensuring that all relevant data is gathered, and that the data is converted from statements and observations into a structured need identification that can be used when evaluating which CMMS to standardise.

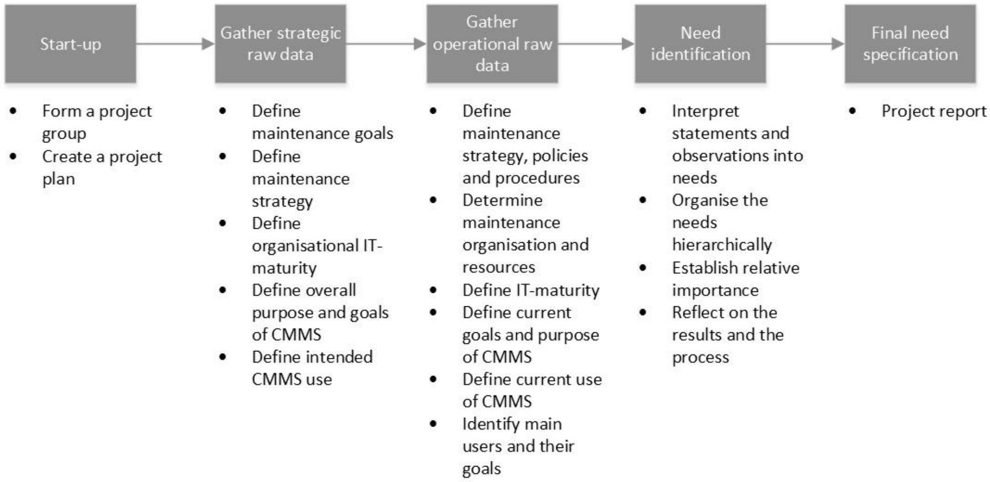

Figure 0.1 The developed need identification process

Key words: TPM; CMMS; Maintenance system; IT-system; Standardisation

Sammanfattning

Bakgrund: För att tillverkande företag skall kunna vara konkurrenskraftiga, så är det viktigt att kontinuerligt sträva efter att eliminera alla orsaker till slöseri. En av de verktyg som kan användas för att bekämpa slöseri är TPM, vilket huvudsakligen är ett strukturerat sätt för att öka företagets tillförlitlighet till sina maskiner och produktionseffektiviteten genom att förstärka företagets underhållsaktiviteter. För att tillfullo kunna realisera fördelarna av TPM, måste stora mängder data samlas, förvaras och analyseras. För att klara av det behövs ofta ett IT-system som ofta benämns CMMS.

Uppdragsföretaget Trelleborg är en industriell koncerns med mer än 100 tillverkande fabriker, där de flesta behöver eller kommer framöver behöva understödet av ett CMMS för att kunna ha en effektiv underhållsverksamhet. Trelleborg såg en potentiell fördel med att ha samma CMMS för alla deras fabriker och ville därför undersöka det vidare.

Problem: Eftersom ett CMMS är hårt knutet till att framgångsrikt arbeta med TPM, så implicerar det fördelen för en industriell grupp att ha ett standardiserat CMMS för att kunna försäkra sig om att varje fabrik har det nödvändiga verktyget för att kunna realisera vinsten av att jobba med TPM. Forskning på implementationen av CMM-system har visat att fördelarna med system kraftigt förminskas om det inte utnyttjas ordentligt och i de flesta fall kan lågt utnyttjande vara resultatet av en otillräcklig urvalsprocess, vilket i sin tur resulterar i att det inte passar organisationen. Alltså, att välja ett CMMS för att standardisera i en industriell grupp är en utmanande uppgift som både har risker och belöningar.

Syfte
Att utveckla en steg-för-steg procedur för att kunna identifiera vilka behov som en industri koncern har på ett CMMS.

Metod: Eftersom författarna till rapporten hade för avsikt att både förstå vilka kriterier som är viktiga att ta i beaktning när ett CMMS ska väljas som standard samt att använda dessa kriterier för att utvärdera vilka specifika behov som Trelleborgkoncernen har av ett sådant system, så användes en abduktiv metod för undersökningen. Studien utfördes genom en ”mixed research strategy”, vilket innefattade både en enskild fallstudie samt en enkätundersökning.

Fokus låg på att sammanföra det befintliga förhållningssättet där varje enskild fabrik agerar individuellt med praxis för en industriell grupp. Detta gjordes för att kunna bestämma vilka kriterier som är viktiga att beakta. Detta gjordes genom att data insamlades med hjälp av flera intervjuer och en enkät. 30 av Trelleborgs fabriker som har ett strukturerat sätt att arbeta med underhåll deltog i undersökningen. Resultatet från datainsamlingen jämfördes sedan med teorin.

Det teoretiska ramverket skapades genom en litteraturstudie, granskning av interna dokument från Trelleborg och intervjuer med både leverantörer av CMMS och anställda på Trelleborg. Detta blev grunden för analysen och utvecklingen av processen för behovsidentifiering och är även grunden till rekommendationerna till Trelleborg.

Slutsats: Ett antal faktorer som är viktiga att ta i beaktning vid en standardisering av CMMS i en industrikoncern kan kategoriseras i sex grupper; grupp, fabrik, individ, system, leverantör och teknologi.

Detta projekt resulterade även i en process för att identifiera behov, utvecklad för att hjälpa industrikoncerner med att utvärdera de ovan nämnda faktorerna för att sedan kunna besluta vilka krav de har på ett CMMS. Applicerandet av processen på Trelleborg resulterade i en lista över behov. Trelleborg ansåg listan vara relevant och det verkade finns möjlighet att hitta ett standardiserat CMMS i deras fall.

Behovs identifieringsprocess: Den utvecklade processen för behovsidentifiering har 5 steg som omfattar: uppstart, datainsamling, behovsidentifiering och specificering. Processen är riktad mot både säkerställandet av att relevant data blir insamlad och att data blir omvandlad från uttalanden och observationer till en strukturerad behovsidentifiering som kan användas vid utvärdering av vilket CMMS som ska användas vid standardisering.

Nyckelord: TPM; CMMS; Underhållssystem; IT-system; Standardisering

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Abbreviations

Table 0.1 List of abbreviation

Abbreviation	Explanation
TPM	Total Productive Maintenance
CMMS	Computerized Maintenance Management System
OEE	Overall Equipment Effectiveness
MTBF	Mean Time Between Failure
MTTR	Mean Time To Repair
MTO	Made To Order
PTFE	Polytetrafluoroethylene
PU	Polyurethane
PM	Preventive maintenance
TPS	Toyota Production System
JIPM	Japan Institute of Plant Maintenance
ME	Manufacturing Excellence
BA	Business Area
BU	Business Unit
WO	Work order

1 Introduction

This introduction chapter will explain the contextual background of this master thesis. It will start by giving the background for the project and a brief introduction of the case company in which this thesis is written in collaboration with. It will continue by presenting the problem formulation, purpose, research questions, scope and delimitations. Finally, a general outline of the report will be introduced.

1.1 Background

In order to stay competitive in manufacturing today, reducing non-value adding activities is crucial. Lean production has in the last decades been a frequently used tool for efficiency and effectiveness improvement, with the aim on reducing waste by streamlining the company's processes (Smith and Hawkins, 2004). However, as most companies nowadays have adapted Lean manufacturing companies cannot simply work with the concept and expect to achieve competitive advantages. To be able to compete on cost, delivery performance and product quality, a well-performing maintenance department is critical (Swanson, 2001).

In recognition of this, an increasing number of companies have started examining the maintenance activities (Swanson, 2001), turning it from a tactical to a strategic area (Carnero, 2015). Effective maintenance is critical to many operations; extending equipment life, increasing its availability and retains equipment in proper condition ensuring it can produce with designed speed and quality. Conversely, poorly maintained equipment can lead to more frequent equipment failures, low equipment utilisation and delayed production schedules (Suzuki, 1994). These issues all limit the efficiency of the plant by forcing them to have comparatively more resources to produce the same results as a plant with better maintained equipment. Additionally, misaligned or malfunctioning equipment may result in scrap or product quality problems (Suzuki, 1994), which makes a plant less likely to produce the desired result, and thereby limiting its effectiveness.

It is clear that equipment health affects the degree of both efficiency and effectiveness that can be achieved, and should therefore be addressed simultaneously with any Lean production initiative. A way of improving maintenance operations has been to employ the holistic maintenance strategy called Total Productive Maintenance (TPM), which aims to improve the function and design of the production equipment. Working with TPM requires greater commitment to maintenance in terms of training, resources and integration, but it also contributes to higher levels of equipment and plant performance (Borris, 2006).

To fully realise the benefits of TPM, a type of software programs commonly referred to as a CMMS (Computerised Maintenance Management System) can be used. The main purpose of the system is to improve the maintenance efficiency by assisting in all of the various processes and procedures of maintenance management by recording, storing analysing maintenance data. Today most of the large and medium sized manufacturers are using some sort of CMMS to support their maintenance organisation, and consequently their production performance (Carnero, 2015).

1.2 Trelleborg Group

Trelleborg group is a world leading manufacturer of engineered polymer solutions that seal, damp and protect critical applications in demanding environments. Their main mission is to always be the customer's number one choice in each of their business areas. The group has about 100 manufacturing sites in 40 different countries, employing over 16.500 people (Trelleborg AB, 2014).

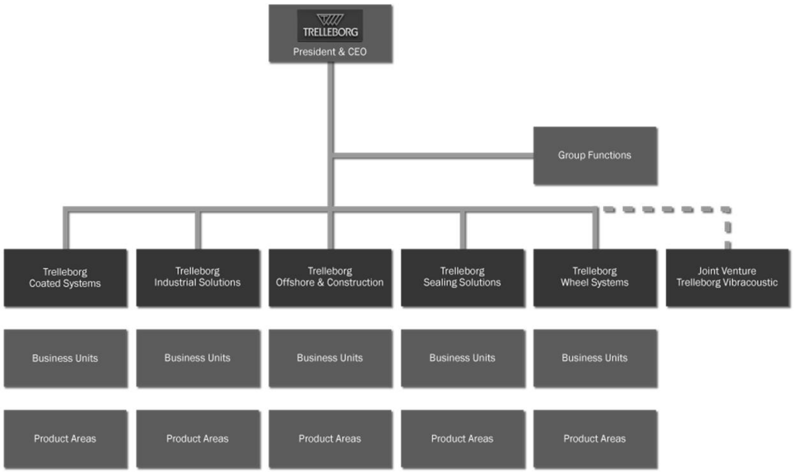

Figure 1.1 Organisational chart for Trelleborg Group

Figure 1.1 shows that it is a decentralised organisation built around five business areas (BA), which in turn consists of a total of 14 business units (BU). The common factor shared by all sites in the group is that they are working with some type of engineered polymers (Trelleborg AB, 2014). There are various degrees of collaboration between the sites within the business areas, but the general level of collaboration is low. Since it is a decentralised organisation, it is up to each individual site to dictate how to carry out their operations.

Even though it is a decentralised organisation there are a number of shared initiatives that works with all manufacturing sites. One of those is Manufacturing Excellence (ME), a strategical initiative which has the purpose of assisting all the manufacturing sites in Trelleborg in their common ambition of producing as efficient and effective as possible.

ME provides guidelines and tools for the manufacturing sites, but since it is a decentralised organisation it is ultimately up to the individual sites how to implement them. The initiative revolves around four pillars; daily management, quality management, flow management and machine reliability, in order to achieve "four zeros"; zero wastes, zero accidents, zero delays, zero defects. The machine reliability pillar is a TPM-initiative, and to support this initiative they have started looking into the possibility to standardise the use of CMMS throughout the group.

1.3 Problem formulation

Current research has shown the benefits that can come with the use of a CMMS, and how it is a powerful tool for enhancing any TPM-initiative (Smith and Hawkins, 2004). Most industrial groups working with TPM creates guidelines or best practices for the initiative on a group level, which then is gradually adopted at the different manufacturing sites. As CMMS is so closely linked to successfully working with TPM (Bohoris et al. 1995), the implication is that it should be beneficial for an industrial group to have a standardised CMMS to ensure that every plant has the tools necessary to realise the benefits of TPM.

What is also shown in the research is that the benefits of a CMMS greatly diminish if the system is not utilised properly (Peters, 2006). Many companies today are not utilising the full potential of their CMMS, and in most cases that is a result of an inadequate selection process, resulting in a poor organisational fit (Mathers, 2003). Consequently, the key to CMMS success, and thereby enabling the full benefits of TPM to be realised, lies in the requirement determination process (Pitts and Browne, 2007).

It is clear that an industrial group can benefit from a standardised CMMS, but the risks are also higher since an inadequate choice will affect several manufacturing sites. There is plenty of research available on system selection, however, they are only addressing the choice in the context of a single plant. Conclusively, even though the selection process is crucial for system success, there is a gap in theory regarding the choice of CMMS in an industrial group context.

1.4 Purpose

To develop a step-by-step procedure that can be used in order to identify the needs of a CMMS system in an industrial group.

1.5 Research Questions

1. What are important factors to consider in the standardisation of CMMS in an industrial group?
2. How can an industrial group determine their needs from a CMMS in a structured way?
3. What are Trelleborg's requirements from a CMM-system?

1.6 Scope and delimitations

Focus will be to identify what needs Trelleborg Group has from a CMMS system by gathering information from several manufacturing sites and combining that information with the corporate TPM strategy. Based on this case a generalised approach will be developed, which then will be applied on Trelleborg Group to determine their needs from a CMMS.

Utilising the needs in a proceeding system selection process in order to test their feasibility is too extensive to carry out within the given time-frame. Therefore, the research will be limited to investigating which requirements that has to be fulfilled by a CMMS in order to suit Trelleborg Group's needs.

1.7 Report structure

Table 2 below is the structure for the report with a description connected to different chapters.

Table 1.1 Structural outline of the rapport

Part	Chapter	Description
Introduction	1	This introduction chapter will explain the contextual background of this master thesis. It will start by giving the background for the project and a brief introduction of the case company in which this thesis is written in collaboration with. It will continue by presenting the problem formulation, purpose, research questions, scope and delimitations. Finally, a general outline of the report will be introduced.
Methodology	2	In this chapter the outline of the way this thesis has been undertaken is described. It starts off by introducing the research philosophy, approach and strategy as well as the scientific approach. Then it goes through the research procedure, and concludes by defining how to ensure research design quality.
Frame of reference	3	The aim for this chapter is to present the theoretical framework of this project. It will start by describing the basics of TPS and TPM, and then proceed to explain what a CMMS is and how it can support the previous topics. The chapter continues with describing an approach to determining system needs, as well as a production development process designed to determine needs and their relative importance from interview statements and observations.
Empirical study	4	Here the information that has been gathered from the Trelleborg's manufacturing sites is presented. It starts by describing the plants which were visited during the project and the output from these visits. Next, the responses from the survey are presented. The chapter concluded by a summary over the key findings of the empirical study.

Analysis	5	This chapter presents the analysis, which is based on the empirical data in combination with the frame of reference The chapter has been arranged under the same topics as in the empirical study. The chapter also includes an analysis of how a CMMS, on a theoretical level, can promote efficient maintenance operations. The chapter is then concluded by a summary of the analysis as bullet points.
Need identification Process	6	This chapter presents the approach for determining the CMMS needs of a group with motivations for each step based on the analysis.
Conclusions	7	To conclude the thesis, this chapter starts with a short presentation of the answers to the research questions. It then moves on to explaining how this thesis has contributed to theory before providing recommendations for the case company. Then, suggestions for future research are presented. Lastly, the limitations of the thesis are discussed.
References	8	Here the references used in this project are presented.

2 Methodology

In this chapter the outline of the way this thesis has been undertaken is described. It starts off by introducing the research philosophy, approach and strategy as well as the scientific approach. Then it goes through the research procedure, and concludes by defining how to ensure research design quality.

2.1 Research philosophy

The philosophy is an over-arching term connecting the development of knowledge and that knowledge's nature. The research philosophy you adopt contains important assumptions about the way in which you view the world (Saunders et al. 2009). The assumptions made here act as the foundation for the research strategy and will motivate the methods chosen as a part of that strategy. As a researcher it is important to be aware of what philosophical commitments are made through the choice of research strategy since it will have a major impact on both the way of working, as well as the understanding of the unit of research (Johnson and Clark, 2006).

2.1.1 Different philosophies

According to Saunders et al. (2009) there are four different philosophies to choose from; *Positivism, Interpretivism, Pragmatism and Realism*, which are presented in Table 3 below.

Table 2.1 Comparison of four research philosophies management research (Saunders et al., 2009)

	Positivism	**Realism**	**Interpretivism**	**Pragmatism**
Ontology: *the researcher's view of the nature of reality or being*	External, objective and independent of social actors	Is objective. Exists independently of human thoughts and beliefs or knowledge of their existence (realist), but is interpreted through social conditioning (critical realist)	Socially constructed, subjective, may change, multiple	External, multiple, view chosen to best enable answering of research question
Epistemology: *the researcher's view regarding what constitutes acceptable knowledge*	Only observable phenomena can provide credible data, facts. Focus on causality and law like generalisations, reducing phenomena to simplest elements	Observable phenomena provide credible data, facts. Insufficient data means inaccuracies in sensations (direct realism). Alternatively, phenomena create sensations which are open to misinterpretation (critical realism). Focus on explaining within a context or contexts	Subjective meanings and social phenomena. Focus upon the details of situation, a reality behind these details, subjective meanings motivating actions	Either or both observable phenomena and subjective meanings can provide acceptable knowledge dependent upon the research question. Focus on practical applied research, integrating different perspectives to help interpret the data
Axiology: *the researcher's view of the role of values in research*	Research is undertaken in a value-free way, the researcher is independent of the data and maintains an objective stance	Research is value laden; the researcher is biased by world views, cultural experiences and upbringing. These will impact on the research	Research is value bound, the researcher is part of what is being researched, cannot be separated and so will be subjective	Value plays a large role in interpreting results, the researcher adopting both objective and subjective points of view
Data collection techniques most often used	Highly structured, large samples, measurement, quantitative, but can use qualitative	Methods chosen must fit the subject matter, quantitative or qualitative	Small samples, in-depth investigations, qualitative	Mixed or multiple method designs, quantitative and qualitative

2.1.2 Philosophy of the master thesis

A major part of the project will be to gain an understanding of how Trelleborg works with maintenance, and what implications that has on a CMMS system. Depending on the local context of the plants, differences in the way of working is to be expected between them. The settings on each plant is most likely a combination of observable phenomenon such as processes, machinery, geographical location and subjective phenomenon such as management and organisational culture. Due to the limited time-frame of the thesis in combination with the fact that Trelleborg Group has about 100 manufacturing sites, a combination of case study and survey was chosen in order to gather enough data to create a representative picture of the group. Conclusively, the philosophy of the thesis has been centred around combining both intepretivism and positivism in order to answer the research question in the best possible way, which is why the thesis adopted the pragmatic research philosophy.

2.2 Scientific approach

The scientific approach has to be in place in order to provide the audience a better understanding of previously conducted research as well as how to proceed in the future. Moreover, it ensures that no approach is taken for granted and enables it to be explicitly discussed (Arbnor & Bjerke, 2009) According to Arbnor and Bjerke (2009) the choice of research method should not only be dependent on the research question, but also on the researcher's view of reality. Based on this they have developed a framework for choosing research approach, which consists of three different approaches; *the analytical approach, the system approach and the actors approach.*

2.2.1 Approach of the thesis

This thesis was carried out according to the systems approach. The systems approach views the reality as mutually dependent parts, which in themselves can be investigated and disclosed through research. However, in order to describe a system, the relations between these parts must also be analysed and understood. As a consequence of this, the results will not be generalizable to every phenomenon, but instead only relevant in the same context. 'It is the researcher's task to create an understanding of a given part of the world, to identify the system parts, links, goals and feedback mechanisms in order to improve the system' (Gammelgaard, 2004). In short, reality cannot be described only by the sum of its parts.

$$Part\ A + Part\ B + Part\ C \neq Reality$$

This approach was chosen as the unit of analysis in the thesis is the maintenance activities at each plant. The way maintenance is carried out at plant level can be viewed as the result of the interaction of several components, of which the main contributors are local management, manufacturing excellence and plant- and process characteristics. It is visualizes below in Figure 2.1.

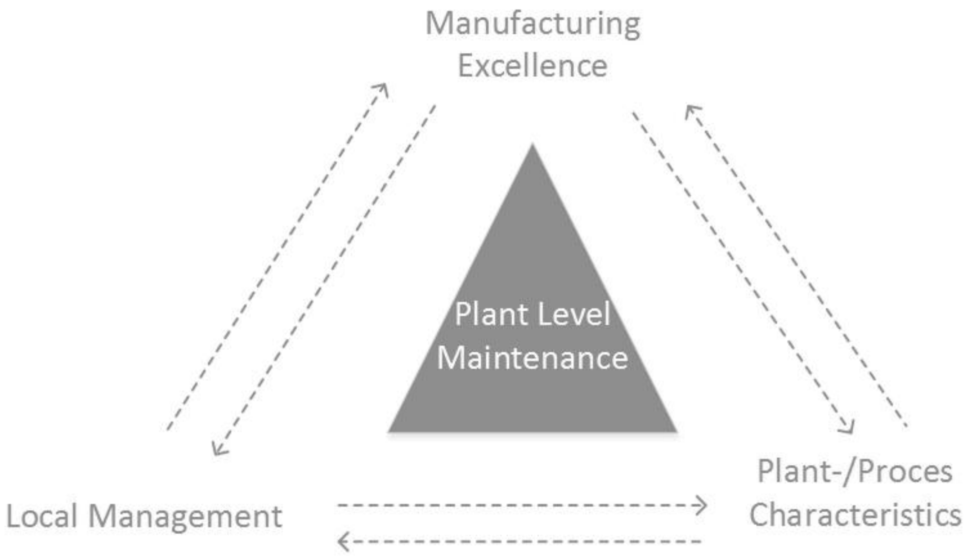

Figure 2.1 Main factors affecting local maintenance

As a decentralised group, it is up to the local management to decide how to manage their production, which in turn makes their work with TPM and maintenance systems subjective. The type of production will also be affecting the maintenance characteristics, as not every plant has the same processes and needs. The local conditions are then combined with the Manufacturing Excellence initiative and its tools to determine how to work with maintenance in an effective way. Conclusively to understand the maintenance at plant level one must both understand the components, and the interaction between them.

2.3 Research approach

2.3.1 Inductive or deductive

There are mainly two approaches to research, the *inductive* and the *deductive* approach. The inductive approach has a primary goal of extending or complementing the existing research by first collecting data, and then developing a theory based on that data. Respectively, the deductive approach is centred on testing the existing theory. It starts with the development of a hypothesis (or hypotheses) by studying the existing theory and then moves on to validating it in the field. It is however perfectly possible to combine different approaches in a study, and it can even be advantageous (Saunders, Lewis, & Thornhill, 2009). This is called an *abductive approach.* The abductive approach will be going through all the steps of both approaches, starting on the inductive side creating a substantive theory, which is then gone through in the deductive process. The abductive approach is shown in Figure 2.2.

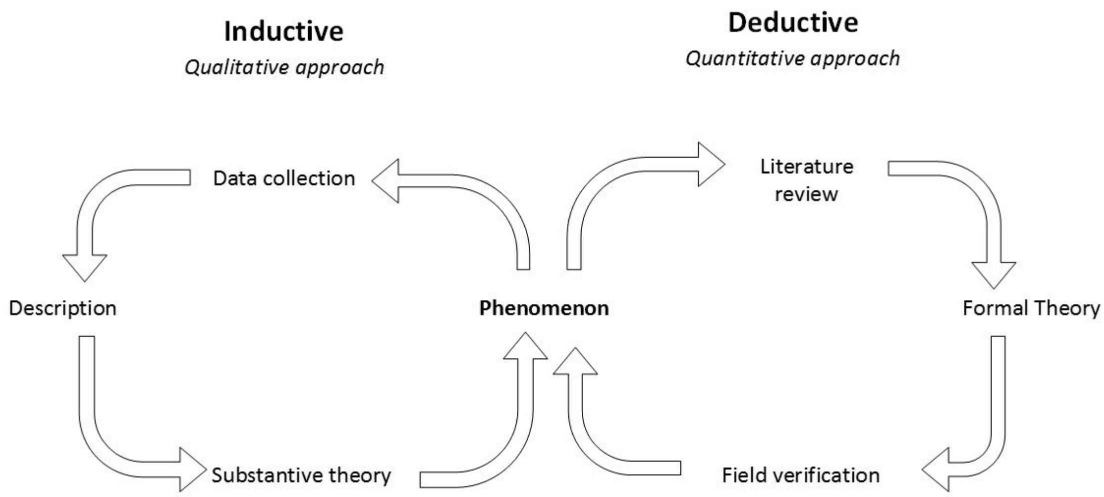

Figure 2.2 Abductive approach (*Woodruff, 2003*)

2.3.2 Research approach in the thesis

The goal of the thesis is to contribute to science by validating current theory in a group context, and then use the findings to extend theory in the field of identifying group CMMS needs. In order to do so, a deductive approach was chosen.

There is quite a lot of literature available in the field of CMM systems, so the study will begin with a literature review on the concept in general as well as approaches to need identification. Based on the literature review, a theory will be formed regarding which factors that are important to look at when determining the CMMS needs of a group. These factors will then be comprised into an interview guide that will be used during a number of site visits in order to determine which of the literature factors that actually are important for those plants, and to gather additional findings. Based on the site visits a survey will be developed that will be used to gather additional data from a number of other plants in the group with the purpose of determining if the findings from the visits are representative for the group. Once the survey is done, the current situation in the group can be described. With the help of that description an approach for determining the CMMS needs in an industrial group will be constructed.

2.4 Research strategy

There are several defined research strategies that can be used, some of them clearly belonging to the deductive approach, others to the inductive approach. However, it is not that simple as just because the research approach is determined that the appropriate strategy is determined automatically. Each strategy can in fact be used for exploratory, descriptive and explanatory research (Yin, 2009). To put it simple, the research strategy is about explaining how to acquire the information needed to answer your research question(s) and objectives. Additionally, factors like the extent of existing knowledge, the amount of time and other resources available, as well as the researcher's philosophical underpinnings will also guide the choice of strategy. However, it is important to remember that the strategies are not mutually exclusive, for example, it is quite possible to use the survey strategy as a part of a case study (Saunders, Lewis, & Thornhill, 2009). According to Yin (2009) the strategies available are: *experiment, survey, archival analysis, history, and case study* and their characteristics are explained in Table 2.2.

Table 2.2 Relevant Situations for Different Research Strategies (Yin, 2003)

Method	***Form of Research question***	***Requires Control of Behavioural Events?***	***Focuses on Contemporary Events?***
Experiment	*How, why?*	*Yes*	*Yes*
Survey	*Who, what, where, how many, how much?*	*No*	*Yes*
Archival analysis	*Who, what, where, how many, how much?*	*No*	*Yes/no*
History	*How, why?*	*No*	*No*
Case Study	*How, why?*	*No*	*Yes*

2.4.1 Phase one strategy

In order to answer research question one, which factors that are important to consider, *how* Trelleborg are working with maintenance and TPM, and its implications on a CMMS has to be determined. How they are working will also be crucial for the third research question, where Trelleborg group's needs of a CMMS is to be determined. This suggest that *case study research* is a good strategy to answer the research questions. Furthermore, as the project focuses on observing and analysing the current conditions, not to alter them, the lack of control over behavioural events is preferred. An important output of the project will be the evaluation of the current ways of working with maintenance, and how a CMMS system can help Trelleborg now and in the future. Therefor there will be a natural focus on contemporary events. Consequently, *case study research* was chosen as the research strategy

2.4.2 Phase two strategy

Even though the complexity of the questions would suggest visiting the majority of Trelleborg Groups 100 production sites in order to gather representative data, the time was a limiting factor in this study. In order to maintain the relevancy, a mixed method was used. The mixed method enables the researcher to more complicated research questions and collect stronger evidence than case studies alone (Yin, 2009). Therefore, the study was conducted as a combination of a case study and a survey.

Survey was chosen as the additional strategy as it allows the collection of large amount of data in a highly effective way (Saunders et al. 2009). This data can then be used to validate if the findings from the case study are representative for Trelleborg group.

2.4.3 Case study

Robson (2002:178) defines a case study as; 'a strategy for doing research which involves empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence'. Case studies are most often used in explanatory and exploratory research. The techniques for gathering data are varying and often combined. Examples used are; interviews, observation, documentary analysis and questionnaires. Therefore, it is common that triangulation is used to ensure that the evidence points in the same direction (Saunders et al. 2009).

Yin (2003), see Table 2.3, defines four type of research designs based on two discrete dimensions; single- vs. multiple case study, and holistic case vs. embedded case.

Table 2.3 Four types of research design (Yin, 2003)

	Single-case design	**Multiple-case design**
Holistic (single-unit of analysis)	Type 1	Type 3
Embedded (multiple units of analysis)	Type 2	Type 4

Since the research questions aims towards describing and analysing the specifics of Trelleborg Group, which then will be used to create more general conclusions, a single case study approach was chosen. However, to gain a representative view of how Trelleborg works with maintenance and TPM, information has to be gathered several production sites. Those sites can be regarded as sub-units in the case, which indicates the study being an embedded case, consequently defining it as a type 2 case study.

Since the case research will cover several sub-units within the same single case, it has much in common with the multiple-case study. Therefore, the case research will be conducted according to the multiple-case study method presented by Yin (2009) described below.

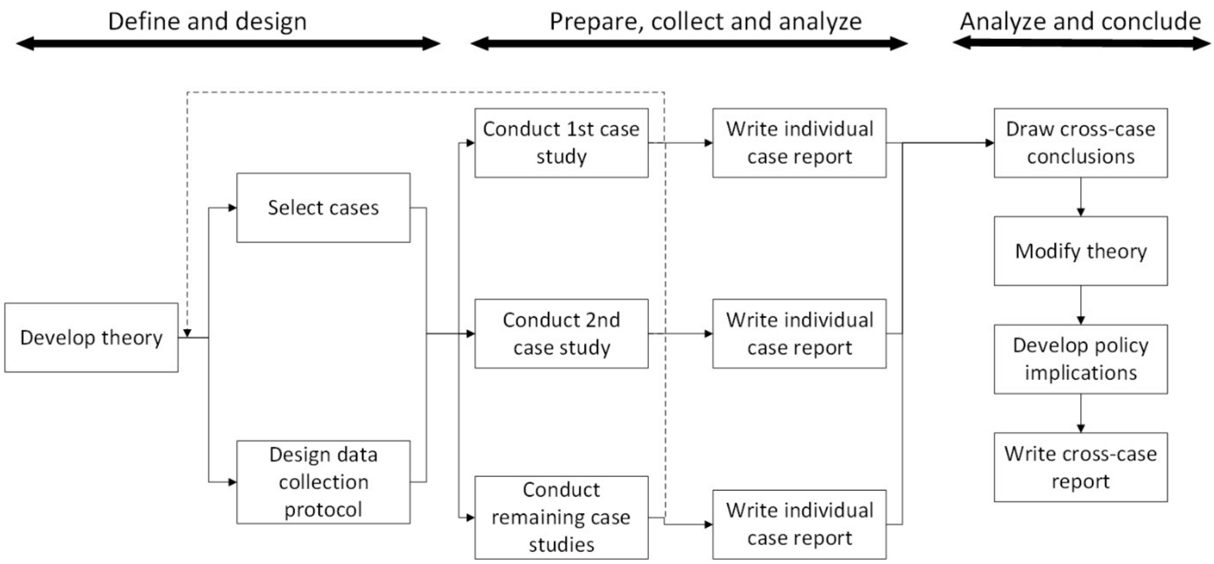

Figure 2.3 Multiple-case study method presented by Yin (2009)

2.4.4 Survey

The survey strategy allows for the collection of quantitative data which can be analysed quantitatively using descriptive and inferential statistics. It is popular in business and management research (Saunders et al. 2009), and contributes to a major part of all logistics research (Gammelgaard, 2004). The main area of use is for exploratory and descriptive research, and it is usually associated with the deductive research approach.

A survey can be described as a data collection technique where different people are asked to answer the same set of questions (Kotzab et al. 2005). There are two types of surveys, self-administered or interviewer-administered, with the main difference being the amount of contact the researcher has with the respondents. It is typically the respondent who completes the self-administered surveys. Such surveys can be administered electronically using the internet or intranet, posted to respondents who return them by post when they are completed, or delivered by hand and collected later. The responses to interviewer-administered surveys are recorded by the interviewer based on the respondent's answers, for example telephone surveys, or structured interviews (Saunders et al. 2009).

In order to yield useful data it is important to base the choice of survey on the research questions and objectives. All of the different types of surveys mentioned above have different strenght and weaknesses, and some important factors to consider are (Saunders et al. 2009);

- Characteristics of the respondents
- Importance of reaching a particular person as respondent
- Importance of the respondents' answers not being contaminated
- Size of sample required for the analysis, taking into account likely response rate
- Type of questions you need to ask to collect the data
- Number of questions needed to collect the data

In order to get the most relevant answers, the person responsible for maintenance on the plants were targeted. The managers are typically used to computers and internet, but they might not be fluent in english. However, it was very important that they answer the survey, as the other functions at the plant usually have rather shallow understanding of the maintenance work. It was semi-important with non-contaminated answers, as the objective of the survey was to really understand how they work with maintenance. In order to get representative data, answers from the majority of the plants who had a well-established maintenance system would be needed. The reponse rate on the other hand, had the potential to be very high, as the survey could be sent out via the site managers. Most of the questions could be answered with multiple choice questions, grading different criteria or statements on a agree to disagree scale.

In this study an internet-based survey was chosen since it allowed for a second person to help out with translation if needed. Although that could lead to slight contamination, it could also encourage discussion with the translator, potentially promoting deeper reflection on the answers. With all the respondents being within Trelleborg Group, they were all available in the internal directory. So by sending a link to the survey by e-mail to the maintenance manager directly, reaching the wanted respondent could be assured.

2.4.5 Data analysis

Once the data is collected, it is of importance to have a general strategy on how to analyse it. In order to achieve this there are a number of analytic techniques that can be applied, which are especially intended to deal with the problem of developing internal and external validity (Yin, 2009).

There are five techniques described by Yin (2009):

- *Pattern matching:* The comparison of an empirically based pattern with a predicted one. If the patterns coincide it can help to strengthen the study's internal validity.
- *Explanation building:* Is actually a special type of pattern matching that has a more difficult procedure. The goal is to analyse the case study data by building an explanation about the case. This procedure is mainly relevant to explanatory case studies.
- *Time series analysis:* Has similarities to pattern matching, but here the phenomenon is analysed over a given time period.
- *Logical models:* The technique consists of matching empirically observed. This technique demands a complex chain of events over an extended time period. The events are staged in repeated patterns where the event at an earlier stage becomes the settings for the next stage.
- *Cross-case synthesis:* Applies specifically to the analysis of multiple cases, while the four earlier were feasible for both single- and multi-case use. It can either be performed on case studies that have been conducted earlier as independent studies, or as a predesigned part of the same study. These cases are then cross-examined and conclusions are drawn whether they have the same implications regarding a hypothesis.

The technique applied in this research will be explained in chapter 2.6 research procedure.

2.5 Data collection

2.5.1 Defining target group

Through initial unstructured interviews it was learned that there was a difference in how much of the TPM concept the plants in the group had embraced, and consequently a difference in how structured their maintenance operations were. Some had been working with it for a while, while others were just starting their journey. Therefore, in order to ensure that the plants used contacted in the case study and the survey could yield relevant answers, a target group had to be selected. Since a CMMS is a tool to enhance a structured approach to maintenance, not a way to create one, interacting with the plants that does not have a structured approach could yield misleading information. Based on this the target group was decided to only include the plants with a structured approach to maintenance. This was considered not to affect the generalisability of the research, as a structured approach to maintenance must be in place before considering a CMMS in order to realise the potential of having such a system.

To assist in the selection, the annual Manufacturing Excellence maturity self-audit, see Appendix A, was used despite the clear bias being present in a self-assessment, as it was the only comparison available. The audit covers all areas of the initiative, and consists of a several topics under which there are a number of describing statements liked to what could be expected from a plant at different levels of maturity. These statements are divided into five levels with a number of statements under each, only if all the statements in one (and all on the previous) level is fulfilled the plant can claim to be on that level. One of the topics were maintenance systems, which had statements connected to having a structured way of working with maintenance. Since a CMMS is a tool to enhance a structured approach to maintenance, the hypothesis was that plants with high rating in this topic should be the ones that could give the most relevant data.

Based on the audit, and some input from Trelleborg Group, a target group was selected, See appendix A. The plants included in this group had a current score of 3 or higher in the maintenance systems topic in the audit. To achieve a rating of 3, the plants had to measure OEE, have both autonomous- and preventive maintenance in use, some degree of strategy for spare parts and more than 50% preventive maintenance. These are all indicators of a structured approach to maintenance, and suggests that those plants are either already using, or would benefit from using a CMMS. Only about one third of Trelleborg's plants have a rating of 3 or higher, so the analysis and the resulting needs will not be based on input from the whole group. However, the remaining plants will continue to work with the TPM-initiative, and should over time develop a structured approach to maintenance as well. At that time their characteristics should be fairly similar to the plants in the focus group as they also work with TPM, and therefore the input from the focus group should be enough to create a good understanding of the group's needs.

2.5.2 Phase one – Interviews

As a fundamental part of the study was to determine how a CMMS could support effective maintenance at the different Trelleborg sites, which requires the understanding of the way of working with maintenance at the sites, the research is more of an exploratory nature. Much of the data needed is of a non-quantifiable nature, such as plant- and process characteristics, local managements view on maintenance and corporate excellence initiative. Such data is best collected by conducting interviews on site, enabling up for discussions and observations which then can be interpreted for deeper understanding (Creswell, 2009). Therefore, the first phase of the data collection was carried out by visiting plants in the group, aiming to collect qualitative data through interviews and observations. Those plants were chosen from the target group, and when taking travel-distance into account six plants in North Europe were scheduled for visits.

The initial plan was to interview key personnel involved in the maintenance process according to theory; maintenance manager, maintenance staff and operators. However, in most cases that plan had to be altered, as the level of involvement of operators varied and some plants had external maintenance staff only.

Each visit was conducted as a full-day event, starting off with a short presentation about the thesis. After that a factory tour was made in order to gain an understanding how the production characteristics, and which implications it had on the maintenance work. The remainder of the day was spent interviewing and discussing maintenance with the key personnel on the site. Finally, a short recap was made before leaving.

2.5.3 Phase two – Survey

In order to gather as much data as possible, a second, less labour intensive, data collection approach was used in the study to complement the site visits. The purpose of this second approach would be to determine whether the factors found during the first stage were representative for the whole group, and to provide numerical data that could be used to determine the relative importance of the factors. Therefore, the second phase of the study was conducted as an internet-based survey, aiming to collect quantitative data (Saunders et. al, 2009).

The survey was directed towards the remaining 24 plants in the target group, that had not been covered by interviews. It was sent out to the site manager at each plant, with the prompt to either forward it to the maintenance manager (on the premise he or she spoke English), or fill it in together with the maintenance manager.

2.6 Research Procedure

The research procedure was inspired by Yins (2009) multiple case study approach, with modification to incorporate the use of a survey to strengthen the empirical base of the project. The procedure is visualized below in Figure 2.4.

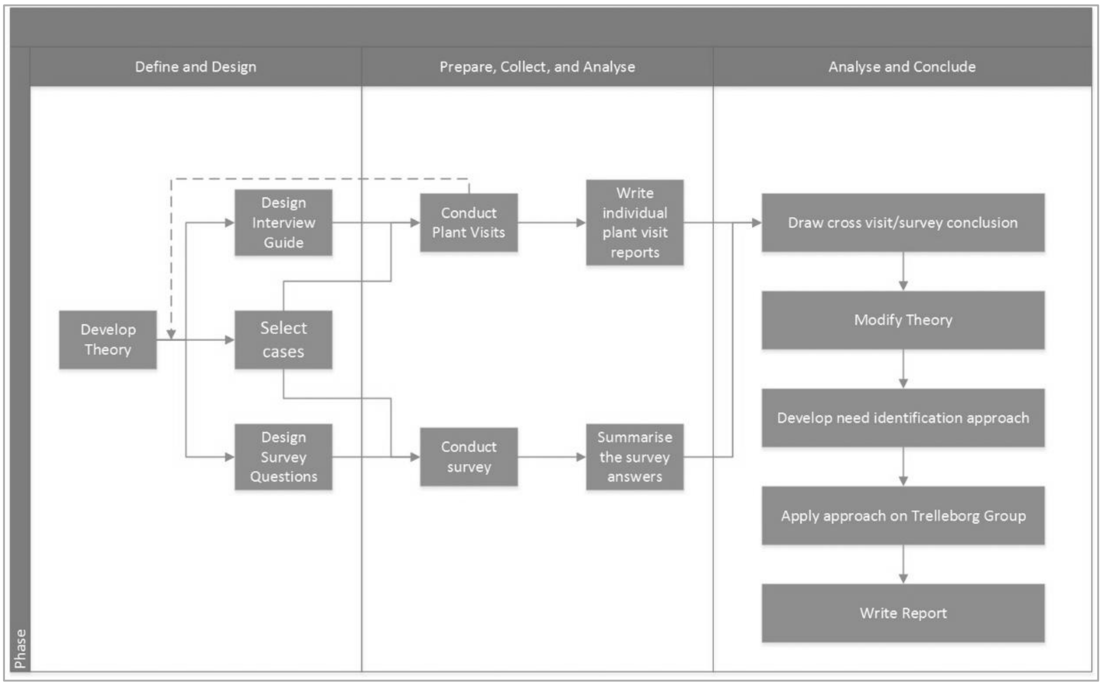

Figure 2.4 The research process for the master thesis. Inspired by Yins (2009) multiple case study approach

2.6.1 Develop theory

As a start of the project, a literature review of TPS, TPM, CMMS and need identification was conducted in order to build knowledge around the project's key components. This would then act as a foundation for the creation of relevant questions for the plant visits and survey, as well as the analysis. The sources of information were books, scientific articles and websites. In the search of articles, the main tools used were Web of Knowledge and Scopus. Additionally, Professor Diego Galar from Luleå University in Technology, researching operations and maintenance, assisted in the search by sharing a number of articles.

The key words mostly used in the on-line search were the following, alone or in combination with each other (combinations shown in table 2.4): An example of search string; "*CMMS requirement identification*".

Table 2.4 Key words and combinations which were mostly used

	Computerised Maintenance Management System (CMMS)	Total Productive Maintenance (TPM)
Implementation	x	x
Evaluation	x	
Maintenance	x	
Need identification	x	
Requirements identification	x	
Selection	x	
Requirements	x	
Total productive maintenance	x	
TPM	x	
Toyota production system		x
TPS		x
Computerised Maintenance Management System		x
CMMS		x

In parallel with the literature review a pre-study was conducted in order to broaden the understanding of Trelleborg Group as well as gather information related to the research subject. To start with, a general introduction to Trelleborg Group and Manufacturing Excellence was given by the supervisor of the project, Victoria Hellström Mader. In connection with this introduction, access to Trelleborg Group's Manufacturing Excellence community and handbook was provided.

When this new information channel was opened it enabled the gathering of much company specific data such as PowerPoint presentations, excellence audits and documentations. The information made available was then analysed in order to gain a deeper understanding of how Trelleborg has embraced the concept of TPM and how that is communicated to the different production sites. In addition to data analysis, meetings were conducted with Johan Kristensson (Project manager IT) and Thomas Persson (Project manager production) to give additional organisational context.

To gain a hands-on experience of modern CMM-systems as well as deepening the understanding of the potential of such a system, two semi-structured interviews were conducted with Swedish CMMS vendors.

2.6.2 Select cases

The proceeding step was the selection of cases, both for the interviews and the survey. The target group based on the ME self-audit mentioned earlier was used to determine which of the over 100 plants to target.

Based on the target group, as well as time and cost, six sites in Northern Europe were targeted for visits. As shown in Table 2.5, was one plant with a lower rating than 3 included, the reason for that being that Hellström Mader had a good perception of the plant, and that it fitted well with the planned itinerary. This exception from the requirement of a score of at least three was justified by the fact that it is a self-audit, which means that the rating is somewhat biased. In that case the manufacturing excellence manager's perception outweigh that rating

Table 2.5 Table over visited sites and their rating in self-maturity audit.

Name	Rating Maintenance Systems	
	Current	Prior Year
Plant A	3	3
Plant B	4	4
Plant C	3	1
Plant D	1.8	1.8
Plant E	3	3
Plant F	3	2

2.6.3 Design interview guide

With the selection done next phase was to develop an interview guide for the site visits, as well as a suggested agenda to communicate what was desired during the visit. The creation of the interview guide started with the identification of the general functions of a CMMS system. The reason being that in order to understand what needs Trelleborg Group has from a CMMS system, the ways such a system can help must first be defined. This information was gathered from scientific articles as well as from different CMMS-suppliers' homepages. Then the information gathered was compared to the Manufacturing Excellence's guidelines in order to determine how a CMMS system can support Trelleborg Group's way of working. The interview guide, see appendix B, was then constructed with the goal of understanding:

- The current way of working at the plant
- The benefits and drawbacks of the current way
- Desired function of a system
- Potential improvements by the use of CMMS

2.6.4 Design survey questions

In parallel with the interview guide the outline of survey questions were created. These were mainly based on the interview guide, but also incorporating the feedback for the different site visits. The survey was divided in to three parts which was individually constructed with the intension of target specific areas. The questions in the survey was based on the interview responses, but it had also been complemented with some additional questions discovered when comparing the responses with scientific articles and literature on the subject. The inspiration to those additional questions came from David (2009) and Cato and Mobley (2002) in their evaluation and comparison of maintenance systems.

The first part was designed to get a general understanding of each separate plant. The purpose was to understand basic characteristic of each plant, for example: where it is located, number of employees and to determine how mature their maintenance organisation was.
The second part of the survey focused on learning about the current maintenance activities and system. A total of twenty statements were presented and the participants had to answer by ranking the statements according to a 5-step Likert scale, where 1 meant fully disagreeing and 5 meant fully agreeing with the statement.

The purpose with the last part was to investigate how the maintenance manager values different characteristics and functions in a maintenance system. Twenty-one questions were asked to rate the importance of different criteria on a 5-step Likert scale, where 1 was not at all important and 5 stood for very important.

2.6.5 Conduct plant visits

Initially, the targeted sites had to be contacted in order to book the visits. Once the confirmed data approached, they got the interview guide and agenda so that could prepare for the visit. The first site visit was done at a local plant, providing a soft start as it was convenient both travel and language-wise. This visit acted as a test of the interview guide, as all the work up until that point only had been on a theoretical plane. Based on the feedback from that visit the guide was slightly reworked in order to improve its relevancy.

After the visit the answers to the questions were summarised, as well as other relevant information and realisations gathered during the visit. This was done as soon as possible after the visit in order to keep the data as relevant as possible. The answers were then sent to the participating plants for review to make sure the answers were interpreted correctly.

The remaining site visits were then conducted with the same, reworked, interview guide. However, each site visit yielded some useful experience and insights that would make the next visit easier. This was mainly information that would alter the way the questions were asked, but not affecting the actual questions. This meant that the researchers experienced an improvement in their way of working for every visit, so in a way it meant continuous, informal feedback to the way of conducting plant visits.

2.6.6 Conduct survey

Based on what was learned through the site visits the survey questions were then updated based on in order to make them as relevant as possible. Since the survey leaves no room for observations, the output of a survey is solely dependent on the quality of the questions asked.

The survey was then sent out to the plant manager of the selected sites, and they were given a two-week timeframe to complete it. If it was not completed within the given time, they were contacted by either e-mail or by phone in order to get them to submit it.

Once all the answers had been collected the results were then visualised with the help of Survey Monkey's report function. The data was then analysed in order to gain an understanding of the implications regarding CMMS systems the survey provided.

2.6.7 Draw cross visit/survey conclusion

Once all the site visits and the survey had been summarised, the next step was to analyse the data gathered and draw cross visit/survey conclusions. In order to do so the following analytical techniques were applied; explanatory building, cross-case analysis and pattern matching.

The analysis started off with *explanatory building*, with the purpose of understanding the way the different actors were working with TPM, and if plant specific processes affected their approach. This was done in order determine in which extent the differences in processes impacted the way they handled maintenance.

The next step was to perform a *cross-case synthesis* between the different embedded cases. The main focus was to determine if the different information sources had the same implications regarding the CMMS systems. Areas of interest were for example the way they were working with TPM today, how they supported that with maintenance systems, how much time was spent on administrating the system, and in which extent information was followed up.

2.6.8 Modify theory

Based on the conclusions from the previous step, *pattern matching* was done between the theoretical framework and the empirical data, with the purpose of identifying similarities and differences, which then could be used to modify theory. Additionally, the findings *were* used to address the group approach. This was needed since the theory developed in the *define and design* phase was based off the available literature, which almost exclusively considered the implementation of a CMMS in a single plant.

2.6.9 Develop need identification process

Once the theory had been modified, it was combined with the analysis results to construct a need identification approach, consisting of activities aiming to map the group's maintenance practices and to derive a need specification from that understanding.

2.6.10 Apply process on Trelleborg

To test the relevance and applicability of the developed approach, it was applied on Trelleborg Group. The first determiner would be if the different activities were actionable, and yielded the output needed to continue, and that the approach produced a final need specification that was usable in the succeeding steps of a CMMS-standardisation. The second determiner was the input given from the Manufacturing Excellence manager, who has good knowledge in both the group initiatives, as well a good overview of the plants. She assessed the approach according to how relevant it was to Trelleborg Group in particular.

2.6.11 Write report

Even though the report was continuously written on during the whole research procedure, the report could not be finished until all the proceeding steps had been completed, since the conclusions and recommendations were dependent on the application of the process. Therefore, the final part of the procedure consisted of completing the report, using the empirics and application to draw conclusions that was used to answer the research questions, and to generate recommendations for Trelleborg Group.

2.7 Research design quality

In order to assure the quality of any social research, four tests have commonly been used (Yin, 2009). As a researcher it is important to pay attention to each one of them.

- *Construct Validity:* identifying correct operational measures for the concepts being studied
- *Internal Validity:* (for explanatory or casual studies only and not for descriptive or exploratory studies): seeking to establish a causal relationship, whereby certain conditions are believed to lead to other conditions, as distinguished from spurious relationships.
- *External Validity:* defining the domain to which a study's findings can be generalised.
- *Reliability:* demonstrating that the operations of a study – such as the data collection procedures- can be repeated, with the same results.

2.7.1 Research design quality of the thesis

Below is the table 2.6 presenting the different quality tests, and which tactics that have been chosen to pass these tests.

Table 2.6 Quality tests (Yin, 2009)

Test	Case study tactic	Phase of research
Construct validity	Gather theoretical data from several research papers, books, websites and interviews	Define & design
	Gather data through multiple interviews and a survey	Define & design
	Have consistency through the research plan, interviews, and case reports	Pepare, collect and analyse
	Let the supervisor at Trelleborg review the gathered data	Pepare, collect and analyse
	Send compiled site data to respondents for	Pepare, collect and analyse
Internal validity	Analyse and compare patterns between respondents	Analyse and conclude
	Use theory to explain discovered patterns	Analyse and conclude
	Involve personnel throughout the organisational hierarchy	Pepare, collect and analyse
	Use multiple site visists and a survey to increase generalizability	Pepare, collect and analyse
External validity	Use interview guide	Define & design
	Create a structured survey	Define & design
Reliability	Compare results with theory	Analyse and conclude
	Gather feedback from stakeholders in Trelleborg Group	Analyse and conclude

3 Frame of reference

The aim of this chapter is to present the theoretical framework of this project. It will start by describing the basics of TPS and TPM, and then proceed to explain what a CMMS is and how it can support the previous topics. The chapter continues with describing an approach to determining system needs, as well as a production development process designed to determine needs and their relative importance from interview statements and observations.

3.1 Toyota Production Systems

Toyota Production System (TPS) was developed by the Toyota Motor Corporation and is today a world-known production philosophy, implemented by many manufacturers in a wide range of industries (Linker, 2009). During the fifties, Toyota started developing their own manufacturing management philosophy. The driving factor in was in their case the shortage of raw material that occurred in Japan as a consequence of the Second World War. The absence of material forced Toyota to develop new, more efficient ways to process the raw material in order to stay in business (Linker, 2009).

TPS is an approach that companies can work with in order to increase their effectiveness and efficiency throughout their entire organisation. In the context of manufacturing, efficiency refers to the ability to use as little resources as possible to carry out a process, while effectiveness refers to the capability to produce the expected results. According to Linker (2009) is TPS built around four pillars: long-term philosophy, the right process will produce the right results, add value to the organization by developing your people, and that continuously solving root problems drives organizational learning. The main goal of TPS is to identify and eliminate all kind of non-value adding activities, which they refer to as muda (waste), muri (overburden) and mura (unevenness) (Linker, 2009).

TPS is often considered to be synonymous with Lean Production, which can be described as a generic description of the philosophy, which better suits the companies in the western world (Samuel et al. 2015). It is important for a company that is considering adopting TPS as their production philosophy to remember that it is a philosophy and not a set of strict rules. A manufacturing plant should have knowledge of all parts of the philosophy and, if they chose to implement it, make sure to apply their own interpretation of the parts (Linker, 2009).

3.2 Total Productive Maintenance

Total Productive Maintenance (TPM) is a manufacturing philosophy that emphasises on equipment maintenance, with the goal of reducing a company's total cost of ownership for their equipment (Dale and Irland, 2006). TPM enhances many of the aspects linked to TPS, especially the mission of reducing non-value-adding activities and the goal of reducing costs for the whole organisation (Andersson et al. 2015).

TPM was developed by the Japan Institute of Plant Maintenance (JIPM) during the second part of the 20th century. It emphasizes on the synergistic relationship between all functions and activities in an organisation, and especially the one between production and maintenance. A well-functioning TPM initiative is a powerful tool for continuously improving product quality, operational efficiency, capacity assurance and safety (Jostes and Helms, 1994).

JIPM defined the philosophy to contain the following five main strategies (Suzuki, 1994):

1. Maximize overall equipment effectiveness.
2. Establish a comprehensive planned maintenance system covering the life of the equipment.
3. Involve all departments that plan, use, and maintain equipment.
4. Involve all employees from top management to shop floor workers.
5. Promote PM through motivation management, i.e. autonomous small-group activities.

The general objective of working with TPM is to maximise the plant´s Overall Equipment Effectiveness (OEE). OEE is a key measure within TPM, and indicates how effectively the production utilises the equipment. The OEE value is the ratio between the effective running time and the required running time, and is calculated by multiplying the three factors: Availability, Performance and Quality (Suzuki, 1994). OEE is further explained in Appendix F.

The number of companies that has chosen to work with TPM has increased rapidly over the last decades, and according to Suzuki (1994) it is because the use of TPM has displayed great results for anyone using it properly. TPM will also improve the workplace's visual appearance, increase the employees' competence level and enhance their skills within the areas that are beneficial to the company.

TPM is based on eight core activities, which are called pillars. Before embracing the philosophy, all pillars need to be evaluated in order to determine which of them that supports the company goals. These activities are: Autonomous maintenance, Planned maintenance, Quality maintenance, Focused improvements, Training, Administration, Safety, Early equipment maintenance (Suzuki, 1994). Each activity is further described in the following subchapters.

3.2.1 Autonomous maintenance

Autonomous maintenance is the expression for when simple maintenance tasks are allocated to, and carried out by operators instead of maintenance employees. This allows the maintenance employees to devote more of their time to more value-adding activities, instead of wasting time on activities that do not require any specific maintenance knowledge (Borris, 2006). Examples of suitable maintenance activities for operators to carry out are; filling oil, changing filters or cleaning.

A large part of the purpose of working with autonomous maintenance is to give the operators a sense of ownership of the equipment at the site. The feeling of responsibility will make the operator more likely to care about the equipment's performance and to report any issues to the maintenance department. The operator is often the person how spends the most time with the equipment, and consequently has the best ability to detect any faulty behaviour (Suzuki, 1994).

Autonomous maintenance is considered to be one of the most important parts of TPM. Working with it has shown to significantly increase the lifetime of the equipment in process industries (Suzuki, 1994).

3.2.2 Planned maintenance

The planned maintenance pillar emphasises on having a structured way of planning when to perform maintenance on which equipment. This is achieved by basing the service intervals on statistics from equipment history in combination with guidelines from suppliers. The statistical input makes it possible to perform a fact based approximation for when and where a breakdown is most likely to occur in the future. The approximation constitutes the foundation for the maintenance interval for the equipment. (Suzuki, 1994)

The purpose of planned maintenance is to perform predictive and preventive maintenance in order to create and maintain the best possible equipment and process condition. The goal is to increase the machine availability by reducing the number of breakdowns, and thereby reducing the waste connected to standstills (Suzuki, 1994).

3.2.3 Quality maintenance

Quality maintenance is about optimising the condition of the processes at the production site, with the ambition of maintaining and constantly improving the quality of the products. By optimising the condition of the processes, quality will automatically be created and built in to the produced product. This is achieved by identifying checkpoints for process and equipment condition that affects quality, measuring these periodically, and if they break the threshold; take appropriate action (Suzuki, 1994; Ben-Daya et al, 2009).

Quality maintenance is a structured way of working in order to integrate quality, and achieve zero quality defects, in the process through improvement of the equipment. When quality is integrated into the process is it unnecessary to perform inspections on the resulting product (Suzuki, 1994).

3.2.4 Focused improvements

The focused improvements pillar describes a structured way of working with improvement activities (Ben-Daya et al, 2009). In order to get the best possible solution to a problem, cross-functional teams should be assigned to a specific project. Thanks to the participants having different positions, they can combine input from different point-of-views, increasing the possibility of finding a satisfying solution to the problem (Suzuki, 1994).

The overall goal is to eliminate identified losses which have been evaluated and found to be waste. The waste elimination will help to reduce the overall production cost and increase the company's profit (Suzuki, 1994).

3.2.5 Early equipment management

Early equipment management is about using experience gathered from already existing equipment and processes, when developing new processes and products. By employing the knowledge from previous implemented equipment, the initial performance for new equipment can be better than the previous (Suzuki, 1994).

The goal is to be able to create projects that are efficient, correct and fast to implement from the very beginning. This will help the company to improve their effectiveness and efficiency and they will be able to reduce the waste caused by employing a trial and error approach (Suzuki, 1994).

3.2.6 Training

The company's employees are their most valuable asset, and they should be trained and educated in areas that are recognised by the company as crucial for their functions. By increasing and broadening the skills among the employees, the company is better prepared to handle the increasingly competitive and technological advance market (Suzuki, 1994). The training could be carried out through, for example, one page lectures, seminars and courses. In order to constantly improve the employee's effectiveness, they should all have individually developed training programs designed to boost their personal development and to increase their knowledge in specific areas (Suzuki, 1994). It should be the responsibility of the company's the maintenance staff and engineers to carry out the training (Dale and Ireland, 2006).

3.2.7 Safety and environment management

Safety and environmental are important issues for companies in all industries, it is essential to keep the employees safe and to not endanger the environment in any way (Borris, 2006). TPM has a clear vision; the production should not have any accidents or cause any environmental damage. This is ensured through the implementation of fail-safe mechanisms on equipment, education of employees in safety issues and to have a process to identify potential risks (Suzuki, 1994).

3.2.8 TPM in administration

TPM in administration is about elimination of losses and waste at the office in a company by streamlining its processes and information flow. The administration within a manufacturing company creates value indirectly by supporting other functions within a company (Suzuki, 1994).

3.3 Computerised Management Maintenance System

A Computerised Maintenance Management System (CMMS) is a computer software program specifically developed to assist in maintenance management, with the purpose of making the maintenance operations more efficient, and consequently improve the company's bottom line (Bagadia, 2006). The idea is to create information that can be seen and used instead of just having a large amount of data which is hard to understand the full meaning of (Peters, 2006).

By employing a CMMS, a company's TPM activities can be enhanced by giving them an organised way of eliminating as much downtime and failures as possible in the production (Carnero and Novés, 2006). A fully utilised CMMS supports efficient maintenance operations, and is an essential information technology tool to be used in order to achieve full performance potential (Bagadia, 2006).

To fully realise the benefits of TPM, large amounts of both maintenance operations- and equipment data has to be gathered. In order to be able to utilise this data, it needs to be collected, analysed and stored in a well-organised way while being presented to the user as information that is possible to handle and act upon. Only a computer system has the capacity to execute those activities and transform the collected data to something useful in an efficient and accurate way (Cato and Mobley, 2002). A CMMS assists the company with those tasks and makes the implementation and work with TPM easier and more manageable (Suzuki, 1994).

There is no strict definition of which functions that a CMMS includes, but most systems include the basic functional capabilities associated with the core modules: work order, equipment management, inventory management, planning and scheduling, preventive- and predictive maintenance as well as purchasing (Peters, 2006). However, in order for the system to be able to perform its operations effectively, it is highly dependent on the input from the user being accurate (Carnero and Novés, 2006). The different modules in the CMMS interact and exchange with each other, so if a source of information is bad, is it likely to affect all parts of the system. Figure 3.1 shows the basic functions which are connected to a CMMS.

Figure 3.1 Core modules of a CMMS.

3.3.1 Work Order

The work order module is by many considered to be the heart of a CMMS (Bagadia, 2006) and it allows the user to generate, view, plan, track, print, follow up and complete work orders (Cato and Mobley, 2002). A work order can be described as a maintenance task which is assigned to be carried out by the maintenance employees, that can be initiated by anyone at the plant. A work order usually contains information describing the issue, who initiated it, when it was reported et cetera (Bagadia, 2006). It is beneficial to use a CMMS to handle the work orders, mainly because it is nearly impossible for a maintenance department to manually process and co-ordinate data with the same level of accuracy as a computer can (Cato and Mobley, 2002). The use of a CMMS also enables two important features; pausing on-going work orders and the possiblity to store work orders planned to be carried out in the future (Bagadia, 2006).

Once a work order is finished, the maintenance employees registers time spent, spare parts used and any comments, thereby enabling the cost of that particular work order to be calculated (Bagadia, 2006). All finished work orders are stored in the CMMS, and this maintenance history is needed in order to perform analyses of the production and maintenance activities (Cato and Mobley, 2002). The work order module is important for the majority of the TPM pillars, as it is the main tool to gather maintenance data. The module also interacts with most of the other modules within the system.

3.3.2 Spare part inventory control

The inventory control module can be viewed as a database that assists the maintenance employees by storing information about the spare parts on site. Every spare part is stored with a brief description followed by information about its cost, lead-time, usage history, et cetera. The module keeps track of where all the listed parts are located as well as their quantity (Bagadia, 2006). Inventory control is considered to be important by most manufacturing companies since a well-structured spare part inventory with accurate records, a spare part locator system and appropriate stock levels can lead to significant improvements of a company's maintenance operations. The module can also inform the user when the stock level for a spare part falls below the reorder point, as well as calculate the economic order quantity for each spare part.

The module makes it possible to have the right spare parts at the right time, which is important in order to achieve both effective maintenance planning and satisfied customers. Effective maintenance planning could also lead to a reduction of both breakdowns and downtime, which are goals for working with TPM (Peters, 2006). The module interacts with modules for equipment management, work order, planning & scheduling, purchasing and preventive maintenance. (Bagadia, 2006). The Inventory control module supports especially the planned maintenance activity within TPM.

3.3.3 Equipment management

The equipment management module is a database that contains every piece of equipment at the site, and any information related to it. Examples of such information is instruction books, pictures, blueprints, drawings and warranty information (Bagadia, 2006). Having as much relevant equipment information as possible gathered at one place makes it significantly easier to find, and consequently making it less time consuming to find equipment information (Cato and Mobley, 2002). Having an equipment management module is also a requirement for being able to record maintenance history for each machine through work orders. The maintenance history is valuable information that can be used to analyse the machines performance as well as its maintenance costs. This data could, for example, be useful in the decision to either restore or replace a machine. This enables the decision to be based on facts and also saves time by having the system do the calculation (Bagadia, 2006).

The equipment management module supports five of the eight activities within TPM; autonomous maintenance, planned maintenance, safety and environmental management, focused improvements, and early equipment management. The module interacts with modules for inventory control, work orders, planning & scheduling, purchasing and preventive maintenance. (Bagadia, 2006)

3.3.4 Planning and Scheduling

The planning and scheduling module in a CMMS is where the work orders are organised and resources are allocated to complete the maintenance tasks. Planning is a central function within the CMMS, mostly due to the importance of carrying out the maintenance plans with accuracy in order to control the maintenance performance and its costs as well as improving craft labour utilization (Cato and Mobley, 2002; Peters, 2006). The scheduling function contains the possibility to develop work order execution schedules as well as features which helps to maintain and display all the schedules. It is possible to attach necessary information like instructions and procedures to the work order to make it easier for the maintenance employees to accomplish the scheduled task. Almost all CMMS's allow the user to use both manual- and automated scheduling, but also to combine the two alternatives (Cato and Mobley, 2002).

The planning and scheduling module interacts with the inventory control, work orders, and equipment management module within the CMMS. (Bagadia, 2006). It also supports the TPM pillars planned maintenance and autonomous maintenance.

3.3.5 Preventive maintenance

Close to all equipment at a manufacturing site needs some sort of preventive maintenance on periodic basis in order to ensure that its operations can be carried out effectively and uninterrupted. The preventive maintenance module in a CMMS is used to create preventive maintenance plans. These plans can be seen as a master plan that, like work order plans, defines what kind of maintenance work that is needed to be done, who should perform it and which spare parts and tools that are required (Bagadia, 2006). However, the preventive maintenance plans are not initially handled as work orders. The plans are connected to one or several pieces of equipment, and each individual plan has its own drivers for execution, either time, frequency or special events. When an execution point is reached, the system will automatically turn the plan into a work order (Cato and Mobley, 2002). The module should also include "route-based" maintenance, which is a list of basic preventive maintenance tasks, such as lubrication or a number of visual inspections that needs to be done by the maintenance staff or the operators at the site. Most CMMS´s handles the routes by generate just one work order for the whole route instead of one work order for every single task on the route (Bagadia, 2006).

Setting up PM-plans is a time-consuming process, but it is possible to predefine plans and reuse them on every piece of equipment that has the same characteristics. This has shown to save a lot of time, especially when there is a large amount of equipment with the same maintenance requirements. These plans are not limited to PM tasks, they can also be used to register safety procedures or any other set of instructions (Bagadia, 2006; Cato and Mobley, 2002). The system should also suggest interval length for preventive maintenance, expressed either as calendar- or run time, which has been optimised based on the information from the maintenance- and equipment history data (Bagadia, 2006).

A CMMS's preventive maintenance module is able to enhance a sites work with preventive maintenance through providing the maintenance employees with a way of highlighting failure trends, displaying major causes of equipment breakdowns and track how much time is spent on unscheduled maintenance (Peters, 2006). The module supports the TPM activities autonomous maintenance, planned maintenance, quality maintenance, focused improvements, early equipment management and safety and environmental management.

3.3.6 Purchasing

Purchasing is a module in a CMMS which enables the users to create and process purchasing requisitions and purchasing orders. This includes ordering, tracking and receiving services and material that has been ordered by the maintenance department. The module can also display the current status for an ongoing purchasing order (Bagadia, 2006). The maintenance department purchasing activities is often separated from the rest of the sites purchasing operations. However, these operations can be linked together by applying a CMMS with a purchasing function, which will become a layer in the ordinary business system. When doing so it is important the information is automatically shared both ways between the two systems, in order to allow them both to contain accurate information (Cato and Mobley, 2002).

By having a purchasing module, required spare parts can be ordered directly through the CMMS which facilitates both a more efficient purchasing process and allows new parts to ordered by maintenance staff straight from the shop floor. Another benefit is the possibility to automatically generate a purchasing order or request when the inventory level of a spare part falls below its reorder point, which assists in always having the needed spare parts in stock. The module should also be able to display and recalculate the price of a spare part into any given currency, facilitating easier price comparison when considering which spare part to order (Bagadia, 2006). The purchase module interacts with, and exchanges information with the inventory control-, vendor-, and work order modules (Bagadia, 2006) and enhances the planned maintenance activity within TPM.

3.3.7 Summary

Table 3.1 is a summary over which modules in a CMMS that supports the different activities in the TPM concept.

Table 3.1 Summary over CMMS modules connection to TPM activities.

CMMS module	TPM activities
Work order	• Autonomous Maintenance • Planned Maintenance • Quality Maintenance • Focused Improvements • Early Equipment Management • Safety and Environmental management
Inventory control	• Planned Maintenance
Equipment management	• Autonomous Maintenance • Planned Maintenance • Safety and Environmental management • Focused Improvements • Early Equipment Management
Planning and Scheduling	• Autonomous Maintenance • Planned Maintenance
Preventive maintenance	• Autonomous maintenance, • Planned maintenance, • Quality maintenance, • Focused improvements, • Early equipment management • Safety and environmental management
Purchasing	• Planned maintenance

3.4 A need identification approach regarding CMMS

When working with TPM, the use of a CMMS system is considered optional, but highly recommended. All should consider it, except for the very smallest manufacturing plants. A successfully implemented and properly used CMMS system can greatly enhance the management of maintenance (Smith and Hawkins, 2004). The most important benefits are related to costs, but other factors like better organisational methods, reduced paperwork and improved communications must also be considered. According to Cato and Mobley (2002) a cost standpoint a CMMS system can help in any of the following cases:

- Planned maintenance is less than 90% of the total maintenance workload
- Craft productivity is less than 80% of capacity
- Craft overtime is more than 10%
- If the finished product quality is consistently less than 95%
- Equipment availability is less than 95%
- Spare part inventory cost is more than 30% of annual maintenance budget

3.4.1 General considerations

In the situation of considering the installation of CMMS, either a new install or upgrading an existing version, it is important to define what expectations or needs you have from the CMMS (Smith and Hawkins, 2004). Because if you don't, the risk is that you end up paying premium for a system with a lot of functions that are not relevant for your way of working. In fact, having too many functions might even obstruct the effective use of the more important functions.

Just because a CMMS is implemented it does not automatically solve the maintenance problems. However, it can be an incredibly helpful tool, given that it is properly implemented and its features are properly utilised. The system is highly dependent on that the data input into the system is correct, or else it will not be able to provide relevant decision support. In order to obtain usable maintenance management information from the system the following requirements are absolute:

- Enter all the facility's relevant data
- 100% data accuracy
- Formats understandable by both user and the software

3.4.2 Information technology needs

Even though the introduction of state-of-the-art information technology has the potential to improve business, the benefits will greatly diminish, or even turn disadvantageous, if not used properly. IT is essentially only technology managed by a user, and if the people do not know how to make use technology, the benefits will not be realised either. In order understand the need of the system, a clear goal and purpose of using the system must be defined. Only then proper use of the system can be assured, and thereby enabling the business to reap the benefits of the IT system (Kans, 2008).

According to DeLone and McLean (2003) there are six factors that measure success in an IT system; systems quality, information quality, system use, user satisfaction, individual impacts and organisational impacts. The system and information quality are the foundation of the system success, they will affect the use and user satisfaction. Which in turn will influence the individual performance, consequently affecting the organisational impact. Figure 3.2 showes how the six factors are connected to eachother.

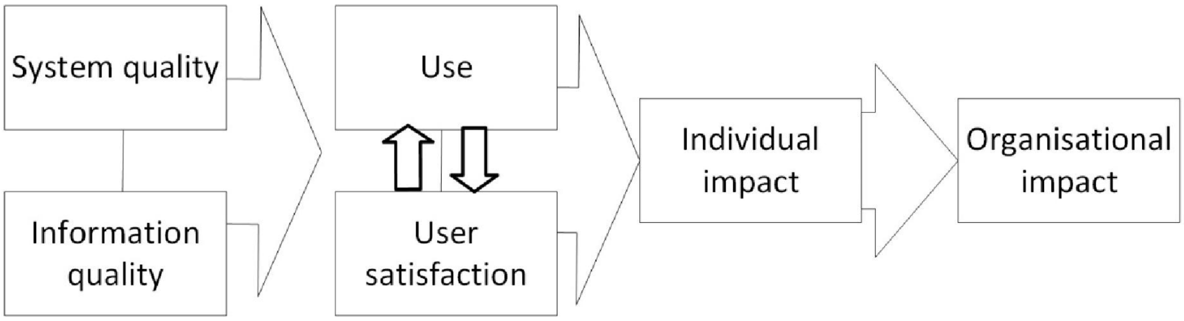

Figure 3.2 Six factors that measure success in an IT system (DeLone and McLean (2003)

However, since the ultimate purpose of using any IT-system should be to support the organisational goals, the process of determining the system requirements should originate from those goals in order to assure organisational fit. By breaking down the organisational goals, individual performance goals can then be determined. The individual impact of the system can then be measured by the relative level of performance improvement and the level of goal fulfilment. However, these impacts are dependent on the purpose of the use, and the way the IT system is supposed to be used. By comparing the intended use to the actual use of the system, the utilisation can be measured. In order to be able to achieve the purpose and enable the proper use of a system, it must have the correct functionality and characteristics. For a system to be considered having "high quality" it should meet both the user and organisational requirements. Delone and McLean's approach is shown in Figure 3.3.

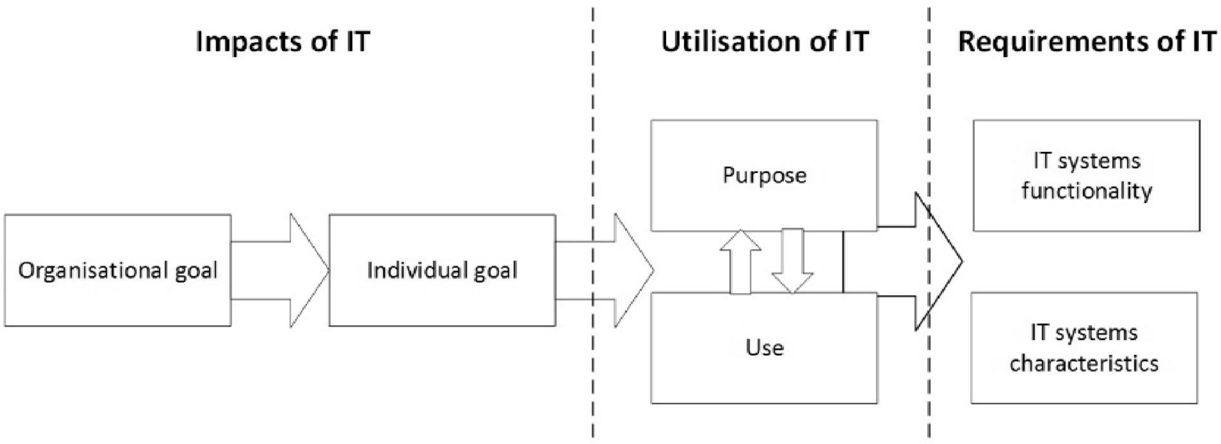

Figure 3.3 Process of determining IT systems requirements (DeLone and McLean (2003)

3.4.3 Determining maintenance management IT needs

In an attempt to bring structure to the CMMS selection process, Kans (2008) created a step-by-step approach, see Figure 3.4, with the goal of defining the requirements for such a system. It started off by applying the model suggested by DeLone and McNeil (2003) in a maintenance management context. As suggested in the model, the starting point was the maintenance organisations goals, i.e. the desired benefits from using a CMMS. Thus ensuring that the technical features of a CMMS needed is based on the business needs.

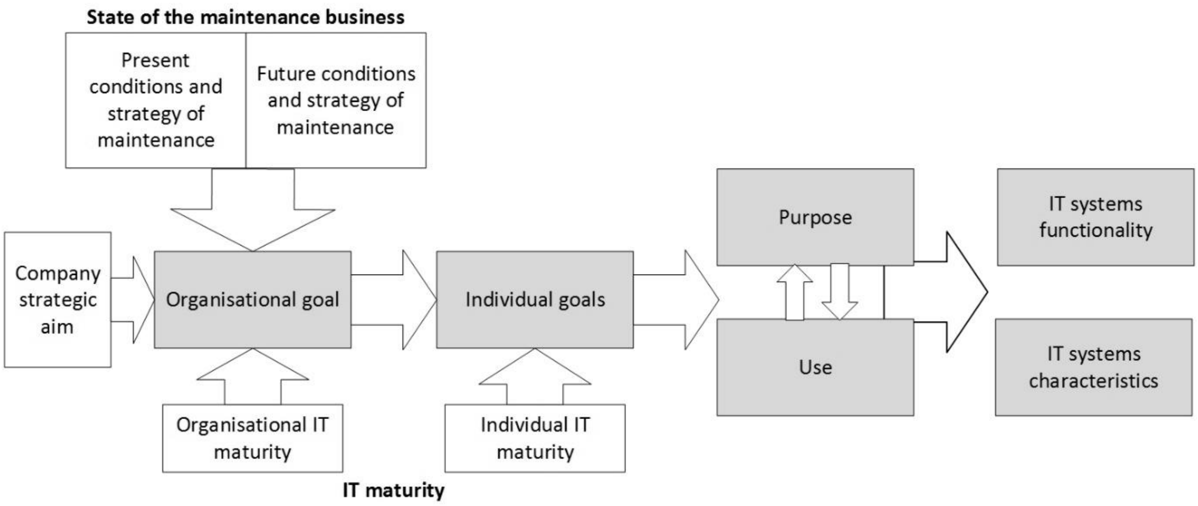

Figure 3.4 Determine IT need for CMMS (Kans, 2008)

As mentioned earlier, the maintenance goals should be a product of the company's strategic aim, and therefore the goals should be identified by breaking down the strategic aim. By applying a fitting IT system for carrying out maintenance, the overall goals of efficiency, effectiveness and cost-effectiveness can be achieved. To determine the fit, the IT requirements should be defined at all levels of management, as the goals and purposes differs between the operational, tactical and strategic level.

Individual goals of the individual user can then be derived from the organisational goals. The purpose and use of the IT system can then be determined based on the maintenance and individual goals. These factors then determine the system functionality and characteristics.

The resources needed for the execution of maintenance, especially personnel and competency, is also affected by the maintenance goals. Therefore, the capabilities and needs of the personnel who will use the IT system is closely connected to the maintenance IT needs. Consequently, the efficient use of IT is dependent on both the organisational- and individual IT maturity. An organisation with low IT maturity will use the system mainly to automate daily tasks and for data storage, while a mature organisation uses it to collect and analyse vast amounts of data for strategic decision making.

As mentioned above, the system must support the current situation, but if the company is working with continuous improvements, the situation might change over time. The higher the maintenance goals get, the greater the need for advanced maintenance strategies, which in turn needs more advanced IT support. So when deciding on IT system needs, both the present and future conditions and strategy of maintenance must be considered during the lifespan of the system.

Users of CMMS are present on all levels of maintenance management (see Table 3.2), using the system for different purposes thus have different needs. Their needs will also be different depending on the individual goals, while the overall maintenance goals are the same for everyone.

Table 3.2 Exemplification of IT demands within maintenance management (Kans, 2008)

	Maintenance management activity level		
	Operational	Tactical	Strategic
Goal	Resource efficiency	Resource effectiveness	Maintenance cost-effectiveness
Purpose	Reporting	Resource allocation	Decision support
Use	Mainly data input (ease of use)	Mainly data processing (planning)	Mainly data output (report generating, IT integration)
User	Maintenance technician	Maintenance coordinator	Maintenance manager

On the operational level, the main use of a CMMS is for reporting, e.g. activities carried out, time consumed for a job or spare parts used. Apart from the reporting the system can be used for finding information needed to carry out daily work, such as instruction books, repair history and spare parts recently used. The main goal here is connected to resource efficiency. As the system is used mainly for entering and retrieving information at an operational level, a basic system requirement could be user friendliness since the process should not be time consuming. Users on this level are usually maintenance staff and machine operators.

On a tactical level the focus is on resource allocation, including for example planning spare part inventory and scheduling personnel. The CMMS's main task here is to support the optimal allocations of available resources, which is highly dependent on vast amount of data being collected and processed in an easy manner.

Strategic maintenance management focuses on making optimal use of assets and resources by conducting maintenance in the best possible way. It is highly dependent on having historical and present maintenance and production data, to be able to analyse the current situation. Additionally, information about news in technology, applications, methods and benchmarking is needed for continuous improvement of the maintenance. Since strategic decisions concerning equipment lifetime assessment is not something the maintenance manager should do in isolation, the capability to share information with other functions like production and quality is an important part of the system.

3.4.4 A model for identifying maintenance management IT functionality requirements

Based on the maintenance management need identification mentioned in the previous chapter Kans (2008) created a procedure for identifying the IT functionality requirements for maintenance management. This procedure is a part of the requirement determination phase, with the aim of determining the functionality and characteristics needed from an IT system. In parallel with process, the data/information requirements should be determined. However, that is not included in the procedure, but can allegedly be easily added in the analysis. The procedure consists of 13 activities, being structured in a workflow with four main steps, and is pictured below in Figure 3.5.

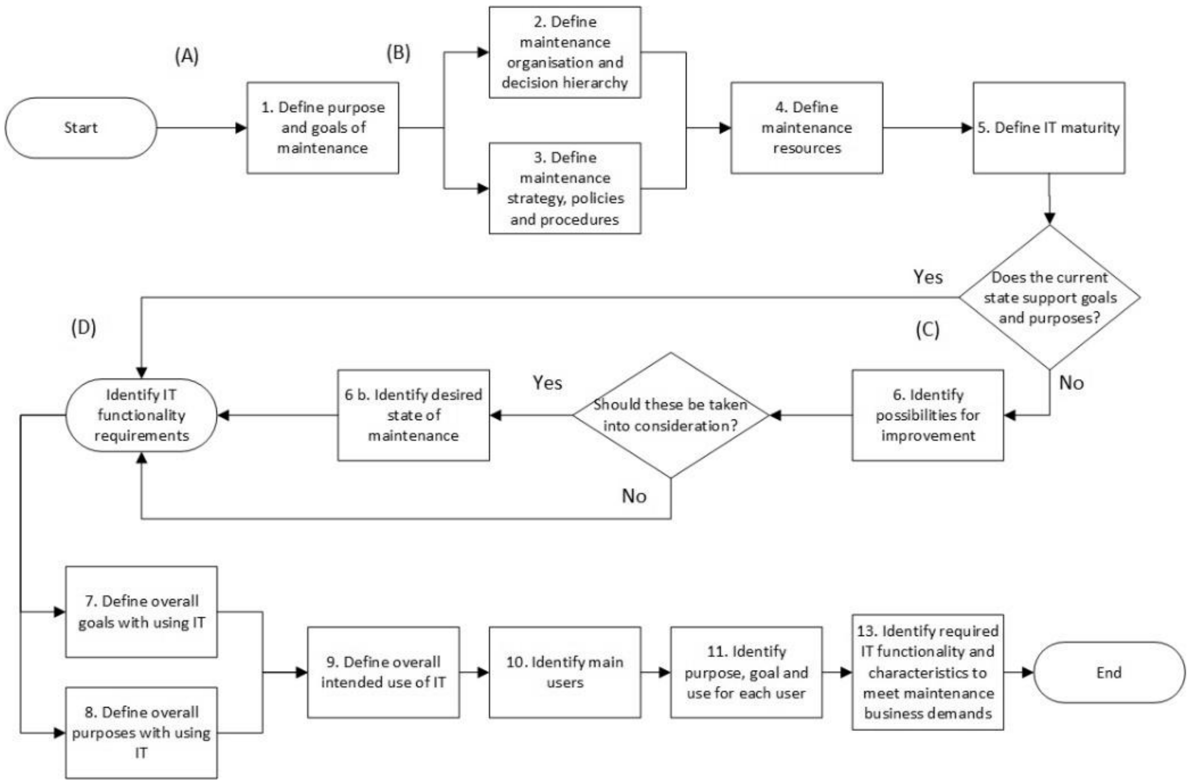

Figure 3.5 Procedure for identifying the IT functionality requirements for maintenance management. (Kans 2008)

3.5 Identifying customer needs

While the model by Kans (2008) described in the previous chapter creates a solid foundation for identifying the functional needs of a CMMS, it does not go into detail of how to do the actual transfer from identification to IT functionality. As the goal of the thesis is to create a process for need identification, some more in-depth instructions are needed on that part. In order to complement the model input was gathered from another discipline where understanding the customer needs also is crucial, namely product development. Therefore, Ulrich & Eppingers (2012) book on product development has been used to interpret the data from the different cases in terms of needs.

In their book, Ulrich & Eppinger (2012) presents "a method for comprehensively identifying a set of customer needs". That method will be described in the following subchapters. The goals of the method are to:

- Ensure the product is focused on customer needs.
- Identify latent or hidden needs as well as explicit needs.
- Provide a fact base for justifying the product specifications.
- Create an archival record of the needs activity of the development process.
- Ensure that no critical customer need is missed or forgotten.
- Develop a common understanding of customer needs among members of the development team.

With this method they wanted to create a high-quality channel for communicating the needs between customers and the developers of a product. It is built on the premise that the ones who directly control the details of a product, must interact with and understand the use environment of the product. If there is a lack of understanding there is a high risk that technical trade-offs are misjudged, innovative solutions to customer needs are missed, and the development team lacks deep commitment to meet the customer needs.

Needs are generally independent of which type of product that is developed, and not specific to the concept that is chosen. It should be possible to identify the needs without knowing how to address them. On the other hand, specifications will depend on the concept selected. The product finally chosen to develop will be dependent on what is economically- and technically feasible, along with customer needs. In their model they use the word need to describe any attribute that a customer desires from a potential product, no difference is made between a want and a need. Customer needs are also referred to in industry as, customer attributes and customer requirements.

Ulrich & Eppingers (2012) method is divided into five steps;

1. Gather raw data from customers.
2. Interpret the raw data in terms of customer needs
3. Organize the needs into a hierarchy of primary, secondary, and (if needed) tertiary needs.
4. Establish the relative importance of the needs
5. Reflect on the results and the process.

Before starting to apply the method, the user should identify a particular market opportunity and define broad objectives and constraints for the project in a *mission statement*. The statement dictates the direction for the project, but neither the destination nor a particular way to proceed.

3.5.1 Step 1 – Gather raw data from customers

In line with the philosophy regarding the high-quality information channel directly from the customer, the first step is to gather information through contact with the customer and experiencing the product environment. The three commonly used methods are;

- **Interviews:** One or more interviewers discuss the needs with a single customer. Interviews typically last one or two hours, and usually takes place in the customer's environment.

- **Focus Groups:** Are typically used when developing consumer goods. A focus group is essentially a discussion with a group of 8 to 12 customers facilitated by a moderator. They are typically conducted in a special room equipped for the purpose of information gathering, with video recording and two-way mirrors so that the group can be observed. The moderator is typically a professional market researcher, and the customers are usually paid a modest fee for attending ($50 - $100).
- **Observing the product in use:** Observing a customer performing a task for which a new product is intended, or use and existing product can reveal important things about the customer needs. There are different ways to conduct an observation, either completely passive without any direct interaction with the customer, or side by side where the observer works with the customer, allowing for first-hand experience using the product. Ideally the developer should observe the product in the actual environment of use.

The interviews are usually the less costly per hour compared to focus groups, and often also allow for experiencing the use environment of the product, it is recommended to use interviews as the primary data collection method.

3.5.2 Choosing customers

When several different groups of people can be considered "the customer" it can be a complicated task to choose which customers to interview. In many cases, one person (the buyer) makes the buying decision, while another person (the user) is the one using the product. The best approach is to always try to gather information from the end user, and in cases where other important stakeholders are present, from them as well.

In the case of the product targeting a single market segment, about 10 to 50 interviews is adequate in order to identify the majority of the needs. If the team wants to gather customer needs from multiple market segments, 10 or more interviews in each segment will most likely be needed. By interviewing lead users and extreme users the needs can be identified more efficiently. Lead users are customers who experience needs months or years ahead of the majority of the market, and who benefits greatly from the product being developed. They are particularly useful to gather data from for two reasons; (1) they have had to struggle with the existing problems not doing what they want, and are therefore often able to articulate their needs, and (2) they might already have invented the solution to their meet needs. By dedicating a part of the data collection to interviewing lead users, it might be possible to identify needs that are explicit for the lead users but latent for the majority of the customers. Interviewing these customers allows a company to anticipate trends and to stay ahead of competition.

Extreme users are customers who use the product in unexpected ways, or who have special needs. An example could be a person with limited vision or dexterity that wants to use a hand tool or a professional using the tool every day (compared to DIY'er). Users like that can help to identify needs that are not experienced as important by the mainstream market, but can be valuable to create competitive advantage.

3.5.3 Eliciting customer needs

The techniques presented earlier has been aimed towards gathering data from end users, but they apply to all data-collection modes and to all types of stakeholders. It is important to be receptive to information given by customers and to avoid confrontation or defensive posturing. The goal is to elicit an honest expressions of needs, and that is not done through telling the customer what he or she needs. Most interaction with the customers will be verbal; with interviewers asking questions and the customer answering. To facilitate a structured dialogue, preparing an interview guide is valuable. Some helpful questions and prompts to include in the guide are;

- When and why do you use this type of product?
- Walk us through a typical session using the product.
- What do you like about the existing products?
- What do you dislike about the existing products?
- What issues do you consider when purchasing the product?
- What improvements would you make to the product?

3.5.4 Step 2: Interpret raw data in terms of customer needs

A customer need should be expressed as a written statement and is the result of the interpretation of the raw data gathered from stakeholders. Each of the customer statements or observations may be translated into any number of customer needs. Different analysts might even translate the same interview notes into different needs, so it is beneficial to have multiple persons involved in the translation process. Below are five guidelines for writing need statements. The first two are fundamental and critical to effective translation; the rest are to ensure a common approach and consistency across all team members.

- **Express the need in terms of what the products has to do, not in terms of how it might do it.** Customers tend to express their preferences by describing a solution concept or an implementation approach. However, the need statement should be expressed in terms independent of a particular solution.
- **Express the needs as specifically as the raw data.** There are many different levels of detail that needs can be expressed at. To avoid losing information, the need must be expressed at the same level of detail as the raw data.
- **Use positive, not negative, phrasing.** The translation from a need to a product specification is easier if the need is expressed as a positive statement. However, positive phrasing can sometimes be difficult and awkward for certain needs, in that case this guideline can be disregarded.
- **Express the need as an attribute of the product.** By describing the needs as statements about the product consistency is assured, and facilitates the translation from needs to specification. Some needs might be hard to express cleanly as attributes, but in most of these cases the need can be expressed as the attributes of the product user.
- **Avoid the words must and should.** These words will create implications of the importance of a particular need, and at this point of the process that should be avoided so that it does not affect the proceeding steps.

The list of customer needs is the collection of all needs elicited from all the raw-data collected. Some of them might not be technologically or economically realisable, but at this stage there should be no such limitations. Customers might also have expressed conflicting needs, but the team should not attempt to address them at this point, merely document them both. The decisions of how to handle conflicting needs, technological or economic factors are some of the challenges of the subsequent concept development activities.

3.5.5 Step 3: Organise the needs into a hierarchy

Step 1 and 2 should result in a list of anywhere between 50 to 300 need statements. That amount of detailed needs is hard to work with, and difficult to summarise in order to be useful in the following development steps. The purpose of step 3 is to put these need into a hierarchical list. Such a list will typically be composed of a set of primary needs, each one being characterised by a set of secondary needs. If it is a very complex product, the secondary needs may be broken down into tertiary needs as well.

The organisation procedure is intuitive, but to ensure rigidity a step-by-step process is suggested. This activity is best performed by a small group of team members at a large table or a wall.

1. **Print or write each need statement on a separate card or self-stick note.** If printing from a computer, it could be useful to print the need in large front in the middle of the card and then the original customer statement at the bottom of the card for easy reference.
2. **Eliminate redundant statements.** The cards expressing redundant need statements can be put together and treated as one card. However, care should be taken not to consolidate needs that are not identical in meaning.
3. **Group the cards according to the similarity of the needs they express.** Attempt to create groups of three to seven cards that express similar needs. The logic for grouping the needs should be according to the needs that the customers view as similar, not what the developers see. This is important as the goal of the process is describing the needs of the customer.
4. **For each group, choose a label.** The label should be a statement itself of need that summarises all the needs in that group. It can be one of the needs in the group, or can be a new need statement.
5. **Consider creating supergroups consisting of two to five groups.** If there are 20 or less groups, a two-level hierarchy is most likely sufficient to organise the data. In that case the group labels will be the primary needs, while the group members are secondary needs. Supergroups should be considered if there are more than 20 groups, creating a third level in the hierarchy. The process of doing so is similar to the previous grouping step, making the supergroups primary needs, group labels secondary needs and the group members tertiary needs.
6. **Review and edit the organised needs statements.** There is no “right way” to arrange the needs in a hierarchy. Therefore, it could be an idea to at this point consider alternative groupings or labels.

In the case of the process being applied in an attempt to reflect the needs of two or more distinct market segments, it gets more complicated. To address this challenge there are at least two approaches. Either each need can be labelled with the segment (and possibly the name) of the customer from whom the need was elicited. This will enable the differences in needs across segments to be observed directly. A technique for visualising the different segments is to use different colours on the need statement cards depending on which market segment it came from. The other option is to perform the clustering process for each market segment separately. This allows the team to observe differences in the needs as well as how the needs are best organised. It is recommended to adopt this parallel, independent approach when the market segments differ greatly in their needs, and it is unclear if the needs of the different segments can be addressed with the same product.

3.5.6 Step 4: Establish the relative importance of the needs

Trade-offs and resource allocation choices will have to be made during the development process, yet in order to do well-founded decisions the relative importance of the needs has to be known. Therefore, step 4 consists of establishing the relative importance of the needs identified in the previous steps. The output of this step will be a numerical importance weighting for a subset of the needs. There are two basic approaches to do this, either to rely on the team members' experience with customers (they know what their customers want), or conducting further customer surveys in to determine importance. While a team can make an assessment of the relative importance of the needs in one meeting, using a customer survey will take at least two weeks. Choosing the approach will be a trade-off between cost and speed versus accuracy. However, in most cases it is worthwhile to conduct a survey.

At this point there should be a connection between the development team and a group of customers that were used in the data-gathering process. These can also be used to rate the relative importance of the needs that has been identified. A general limit of how many needs to ask the respondents to rate are about 50, it should be enough to cover the important ones while ensuring that it is not too time consuming. Many needs will also be either obviously important or easy to implement, therefore the scope can be limited to asking about the needs that could lead to difficult technical trade-offs or costly features.

3.5.7 Step 5: Reflect on the results and the process

The final step is to reflect on the process and its results. While the process of identifying customer needs can be carried out in a structured way, it is not an exact science. The results should be challenged to verify that they are consistent with the knowledge and intuition that has been developed by the team during the process. Some questions designed to help reflecting on the process:

- Have we interacted with all of the important types of customers in our target market?
- Are we able to see beyond needs related only to existing products in order to capture the latent needs of our target customers?
- Are there areas of inquiry we should pursue in follow-up interviews or surveys?
- Which of the customers we spoke to would be good participant in our ongoing development efforts?
- What do we know now that we didn't know when we started? Are we surprised by any of the needs?
- Did we involve everyone within our own organisation who needs to deeply understand customer needs?
- How might we improve the process in future efforts?

4 Empirical study

Here the information that has been gathered from the Trelleborg's manufacturing sites is presented. It starts by describing the plants which were visited during the project and the output from these visits. Next, the responses from the survey are presented. The chapter concluded by a summary over the key findings of the empirical study.

4.1 Plant visit

Below is a general description of every plant visited in the empirical study. As the sales and volume figures is sensitive information for the case company, the output of the plants has been graded from low to high volume relative to each other in order to create some additional context when comparing the answers from the plants. Connected to each description is a flow-chart describing the maintenance process of that site, which is presented in Appendix C.

4.1.1 Plant A

Plant A is a low/medium volume plant with a jobbing process layout. Production is Made-To-Order and they mainly process elastomers in their production. The majority of the machines are of medium size, and there are a few critical machines in the plant. The maintenance department consists of 13 people, all employed on site, and there is a full-time maintenance manager.

Plant A was using a recently acquired modern CMMS system, which included all the expected core functions and is using the majority of them.

4.1.2 Plant B

Plant B is a high-volume plant that is utilizing both line and batch processes. The base of the products are elastomers, but it is often combined and integrated with metal. They have several critical machines in the production, and the machine park consists of large, medium and small machines.

The maintenance department is managed by the production managers (there were two) in their respective parts of the plant. As production managers they have many other tasks taking attention from maintenance. The maintenance department consists of 1 internal and 3 external personnel with varying competencies, the external being on site several days a week.

They have designed their own maintenance systems at the plant, which is a combination of a Lotus Notes-based solution and an Excel spreadsheet.

4.1.3 Plant C

The production process of plant C is a combination of jobbing and batch processing, consisting of several small or medium sized machines. This medium volume plant produces MTO products made of either PTFE or PU compounds. The production is highly automated, employing several shop-floor robots, but few of the machines are critical.

Maintenance management is a part of the Process Technical manager's responsibilities, meaning that maintenance only gets part-time attention from the manager. The maintenance department consists of 4 internal- and some external personnel with special competencies present at the site on regular basis.

They are using a CMMS, however, it is old and does not have any support available from the supplier anymore. The functions they use are reporting work orders and the generation of weekly PM-plans.

4.1.4 Plant D

Plant D is a low volume plant working mainly with a jobbing type process, making their products out of polymer composites. The production is mainly MTO, utilizing small and medium sized machines of which a few of them are critical.

They have a full-time maintenance manager handling the maintenance department, which consists of 2 internal and 2 external personnel with special competencies (present at a regular basis). This plant relies on an Excel-based maintenance database for planning the preventive maintenance. There is also a paper-based system in use for creating maintenance work orders.

4.1.5 Plant E

The production in plant E is of low-volume and uses a batch production process, mainly producing components of elastomer materials according to customer orders. Most of the machines in the plant are small, and they do not have any critical machines as they have multiple machines of each type.

Maintenance management is one of the tasks recently assigned to the Engineering manager, who has other responsibilities as well. The maintenance department consists of 3 external contractors with different competencies that are on site a few days a week.

They are using an, at least, 10 years old CMMS, which seems to include all the functions expected from such a maintenance system, see chapter 3.3. However, the only function currently used in the system is the preventive maintenance module.

4.1.6 Plant F

Plant F is a small-volume plant producing products MTO with a jobbing type process, utilizing both PTFE and metal. The machine park consists almost entirely of small machines and among them only one or two that are critical.

This plant has an appointed maintenance manager who spent full-time on maintenance related tasks. There are three employees with varying competencies working at the maintenance department, taking care of the majority of issues in the production. External contactors are also brought in for special tasks.

The plant is using an old CMMS system for generating weekly PM-plans, and a Microsoft Excel solution for reporting non-critical issues.

4.2 Plant visit data

Below is a compilation of the information gathered through interviews and observations from the plants visited.

4.2.1 TPM-general - effects of implementation

When asked to describe what TPM was, the general answer was to involve the operators in the daily maintenance work in order to achieve better process performance using the available resources. Plant C also mentioned preventive maintenance as a part of the concept, but in general there is no uniform view of what defines TPM.

Every plant in the study had embraced the planned maintenance part of TPM, using some kind of system to determine which actions to take on a weekly basis. So even though most of them did not regard planned maintenance (or preventive maintenance) as a part of TPM, they had all applied it. This might be a result of the intuitive nature of the concept; it is always better to deal with an issue in a controlled manner instead ignoring it until it becomes a serious problem, potentially resulting in a breakdown.

Half of them had also implemented autonomous maintenance in their production, some through the whole production site, others in certain parts of it. For the plants who had embraced it, most of them had experienced positive effects in two areas; maintenance staff got more time to spend on more advanced maintenance tasks, and that operators took more responsibility over the machines. Even though they had experienced some resistance in the beginning, transferring certain tasks to the operators had been predominately successful. However, all plants had the same problem with the concept; that there still were some operators not embracing it.

4.2.2 Continuous Improvement

When it comes to continuous improvement the different sites had varying approaches to the concept. In plants A, B and C improvement suggestions could come straight from operators in different forms, either as written suggestions or verbally during production meetings. In plant D and F, the operators also came with suggestions, but in that case they had to go via the supervisor who then forwarded it to management. The improvement suggestions in plant E came from management or the finance department, who based the areas of improvement on figures.

Once the problem had been identified, the approaches to solving them varied widely. Plants A and E appointed a responsible for the issue, plant C worked in cross-functional teams to solve the issues, plant D put it in the preventive maintenance plan while plants B and F handled them as projects. Even though every plant has a way of both identifying and working with improvements, only plant A and F has a structured way of following up on them. Both those plants set goals for the projects, which are then followed up on either monthly (plant A) or when the project is done (plant F).

4.2.3 Collaboration

As mentioned in the introduction, Trelleborg Group is a decentralised organisation, and that is reflected by the degree of collaboration that the plants have with other group members. Plants A, B, C and F had some collaboration through a production performance benchmarking program with other Trelleborg sites in their own business area. In some plants the local manufacturing excellence initiative had promoted contact with other plants, which was utilised by plants A, D and F, although in D’s case it was mainly sharing information (and not receiving any). Except for benchmarking, most communication between the sites originated from the personal networks of managers at different levels.

Only plants A and D believed in the possibility to share inventory, given that they used the same type of spare parts for their machines. Plant C did not want to share inventory with other plants, but could see a benefit in being able to view what other sites had in stock so they could purchase the item from them if there was an urgent need and long lead-time. The other sites had no interest in a shared inventory.

Even though the collaboration between sites was limited, all the sites were positive to increasing it. They were especially interested in more dialogue and experience sharing between managers, in order to facilitate better decision making and get improvement ideas.

4.2.4 IT-skills

The general IT-knowledge in the plants was decent in all cases, and the personnel handled the available systems satisfactory. However, this uniformity in answers might be influenced by the fact that all sites visited were located in Northern Europe, where the computer skill generally is high among the population.

All plants had an ERP system, so all the blue collar staff already had some interaction with an IT-system. Plants C and F also worked with barcode scanning to input information into the machines or systems, and felt that it had simplified the routines. Plant F was also working with tablets in parts of the production to view blueprints, work instructions and to report jobs. Once the personnel had gotten used to it, it had been working well for operators of all ages.

4.2.5 Autonomous maintenance

While all plants had the operators going through daily inspection checklists to review the machines condition, only plants B and D had put the responsibility on the operators to address some of issues they could encounter. Examples of actions could be lubrication, fill oil, change oil filter, tighten bolts or clean. Although plant C claimed they did not work with autonomous maintenance, they did have their operators cleaning the machines.

Every plant had instructions on how to do the daily inspections, and in the case of B and D how to perform autonomous maintenance, located at each machine. Those instructions had in every case been developed by the maintenance department, and sometimes in collaboration with the ME- or production manager. In plants A, B and D, the time it took to carry out these activities were approximated when they were implemented. However, none of them had a way of tracking how much time was actually spent on autonomous maintenance. Additionally, it was only plant A that monitored their machines performance.

4.2.6 Reactive maintenance

In general, the way of making the maintenance department aware of an urgent issue was by phone. In plant A, B, C and F the operator determined if maintenance was needed and contacted the maintenance department directly. In the rest of the cases, the operator first spoke with the supervisor, who assessed the issue and then contacted the maintenance department if it seemed necessary. In plants A, B and C, the maintenance department created a corresponding work order in the CMMS after solving the issue, which they then directly finished reporting time spent and spare parts used in order to record the repair in the system. In plants D and E, they utilised a paper-based work order system. When an issue was identified a job-card was filled in describing the issue, its priority and which machine it referred to. This job-card was then picked up by the maintenance staff, who then filled in time spent and spare parts used when the issue was solved. The card was then given to the maintenance manager, who manually had to enter the information into the maintenance system. However, when there was a really urgent issue, there was a risk that a card did not get filled in. Plant F did not record any maintenance at all.

The operators themselves took little part in the reactive maintenance at the plants, it was only in half the cases (B, D and E) that they fixed anything themselves, and that would only be very simple things that they had experienced before.

All plants had a strategy for prioritising certain machines for maintenance, some had a fixed prioritisation stated while others had situation-based prioritisation, for example if a machine was critical for fulfilling an urgent customer order.

All plants that were reporting into a maintenance system, except for plant A, felt that the input could be done in a smoother way. The main concern was that the current way of reporting was unnecessarily time-consuming, creating double-handing of information, and that the systems were generally non-user-friendly. Among the suggestions on how to improve it, automated information gathering from the machines was highlighted, so that all input into the system did not have to be manual. Plant A was the only plant that had any automated tracking, but that was through their ERP system, and that data never reached the CMMS.

4.2.7 Preventive maintenance

As mentioned earlier, preventive maintenance was something that all plants had embraced, and for the ones with a CMMS (A, C, E, F), the main use of that system was the generation of weekly preventive maintenance work orders. The plants without a CMMS (B and D) also worked with weekly PM plans, but in B's case was it generated by their Lotus Notes program, while the maintenance manager at plant D manually created the weekly task lists from an Excel database. Which tasks to include in these plans were in all plants defined by what was recommended in instruction books (plant A also based it on experience). Only plant C updated these intervals regularly; if for example a perfectly fine ball-bearing was changed according to the PM plan, the interval for that change would be extended.

A problem for some of the plants was that the maintenance intervals in the system had not been reviewed in a long time. This lead to the system generating work orders for actions that were not relevant anymore, or even suggesting maintenance on machines that no longer existed.

4.2.8 Follow-up on maintenance

The only plants doing regular follow-ups on maintenance performance was plant A and C. In plant A there was a maintenance meeting every other week where unplanned machine stops, which was their main KPI, was evaluated. Plant C worked with regular check-ups on machine performance in order to determine how well the maintenance department managed to keep the machines in desired condition.

Plant D was the only plant that had attempted to track OEE, however the way their current system worked made it very time-consuming, and they did not do it anymore. In general, all plants (except for A) had a hard time finding good information to base their follow-up on. A contributing factor to this issue was that the system did not provide an easy way to create and customise reports. For example, maintenance costs per machine was something that none of the plants visited had an easy way of determining. In plant A they handled it by asking the controller to summarise the costs for a specific machine. In plant C the information was in the CMMS and ERP system, but summarising them required quite some work. The other plants had no effective way of determining the costs.

The majority of the plants wanted to have an easy way of evaluating cost per machine. The ability to evaluate downtime and spare parts used was something that plant E wished for as well.

4.2.9 Personnel

At the moment none of the plants had a structured system for keeping track of internal and external resources, their competencies and costs. In plants A and B the maintenance manager had the costs of the regular contractors written down, but they were not in the system. The rest did not keep track of them at all. The maintenance departments were pretty small at all the sites visited, so none of them experienced any need of having a system helping them keep track of where each of their personnel were allocated.

The maintenance labour costs were not followed up in any of the plants, although plant A wanted to put it into their CMMS.

4.2.10 Data gathering & Information handling

Machine related information was handled differently among the plants, in plant A, E and F the majority of the documentation was in digital form and stored in the CMMS (not for plant F). The other plants had most of their documentation in physical form, partly because no one could spare the time to digitalise it. Plants A, B and C also had maintenance history connected to each machine stored. The stored information was used for reference when repairing at every site, but plant C also used it to evaluate the set PM intervals.

The information stored for each machine was in most cases only reviewed when a new machine was bought, moved or in connection with a legislation change. Plant C was the only one having a continuous process for updating the information, additionally they had an internal audit that checked the integrity of the data.

All input of data into the CMMS was done manually at stationary computers in all plants. At plants A and C information about downtime and quality was recorded automatically in other systems, however it was not connected to the CMMS. In plants A, B, D and E the job reporting process involved some degree of double-handling, usually the work orders ended up at the manager's office who then had to enter all the information, that already had been written down on paper, into the system. This lead to the managers spending a noteworthy amount of time each week reporting work orders into the system. All plants also had the issue that all time spent on maintenance only was an estimate, as there was no automatic tracking of the downtime between the initiation of a repair until the machine was up and running again.

4.2.11 Spare parts handling

Plants A and B were the only ones keeping track of their spare parts in the maintenance system. In plant A they also had them arranged in storage, while plant B only knew which parts were in inventory, but not their location. All of the plants tried to keep as few spare parts as possible in stock, and would not stock any part they could get the same day, or the day after.

Plants A, B and C also tracked the spare parts used in the repairs, given that it was recorded in the work orders. However, in the case of plant C the parts used was only recorded as text, so it was a bit less useful in the system.

4.2.12 CMMS questions

The rationality behind the choice of the current maintenance system differed; plant A choose their current system because it was easy to work with, plant B created it after what they felt they needed at that time, plant D went with their excel-based solution because of its simplicity, and the rest had old systems that were chosen by previous manager for unknown reasons. In all cases except for plant B, it seemed like the maintenance department had chosen the system on their own, without involving any other functions.

4.2.13 Functionality

The only plant using a modern CMMS was plant A, and they were fully satisfied with the way their system worked. Plant B who had designed the system after the need they experienced were also satisfied with the way it worked. Plant C enjoyed the simplicity of work order generation, and that it was easy to navigate in the machine register. Plant D with their Excel based solution felt that it was visual and simple.

All plants used some kind of preventive maintenance function, even though the way the work orders were generated varied. Plants A and B also had some kind of spare parts handling function. The CMMS was also used for storing machine related information in plants A, C and E. Plant A also utilised their invoice module. A CMMS contains more functions than the ones mentioned above, and all plants that had such a system stated that there were some functions that they did not use.

4.3 Main takeaways

The key takeaways from the empirical study are presented below in Table 4.1.

4.3.1 Plant visits

Table 4.1 Key findings from plant visits

TPM-general	• The plants had a varying perception of TPM - No plant mentioned all the pillars • All plants were working with preventive maintenance • Half of the plants had implemented autonomous maintenance • One common problem; not all operators embracing it
Continuous improvement	• Varying ways of identifying and handling improvement opportunities • Only two plants measured the improvement
Collaboration	• Four sites benchmarked their production performance against other Trelleborg plants in their own business area • Most other communication between sites originated from personal networks • Positive attitude to increased information sharing • Two sites were positive towards shared inventory
IT-skills	• The IT-skills among the personnel were good enough to handle the available systems • All sites had an ERP-system • Two sites used scanners for information input • One site used tablets on the shop floor
Autonomous maintenance	• All plants had operators performing daily inspections • Two plants had the operators address issues like lubrication, change filters, tighten bolts etc. • All plants had written instructions on daily inspections and autonomous maintenance at the machines • No plant had a way to track time spent on autonomous maintenance
Reactive maintenance	• General way of reporting an urgent issue was by phone • Four plants had the operators contact the maintenance department directly • Two plants had the supervisors evaluate the issue before contacting maintenance department • Three plants reported into the CMMS by creating and finishing a work order after the issue had been resolved • Two plants used a paper-based work order system • Operators took little part in the reactive maintenance • Main issues with the current systems were; too time consuming, double-handling of information and lack of

	user friendliness
Preventive maintenance	• All plants were working with preventive maintenance • PM-plans was the main purpose of their maintenance systems • Actions based on instruction books • One site worked actively with updating their intervals • Some of the sites had problems with obsolete plans
Follow-up on maintenance	• Two plants did regular follow-ups on maintenance performance • The only plant that had tried to track OEE was plant D • All sites except one had problems finding good information to base their follow-ups on • No plant had an easy way of determining maintenance costs per machine, but it was something they wanted to have
Personnel	• None of the plants had a structured system for keeping track of internal and external resources • Maintenance labour costs were not followed up in any of the plants
Data gathering & information handling	• Half of the plants had the majority of the machine information in digital form, and the rest had the majority in physical form • Half of the plants stored the maintenance history of each machine • Only one plant did continuous reviews of the information in the CMMS • All sites did their data input into the system manually at stationary computers • Every plant reporting into the CMMS had problems with double-handling of information • No plant had a way to automatically track time spent on maintenance
Spare parts handling	• Two plants were keeping track of their spare parts through their maintenance system • One plant had stock locations for the spare parts • No plant had spare parts in stock that they could get the same day or the day after • Three plants recorded spare parts used in repairs
CMMS questions	• The reasons behind the system choice were; ease of use, developed after their needs or unknown
Functionality	• The plant using a modern CMMS was satisfied with the way it worked • No plant used all functions available in their system

4.4 Survey

This section presents the compiled answers from the survey, for more details regarding the survey and the raw data gathered, please refer to appendix E.

4.4.1 TPM-general - effects of implementation

Most of the respondents regarded TPM as an important concept to work with in order to improve the efficiency of their operations. While not all respondents fully agreed to the statement, none of the surveyed fully disagreed to TPM being important.

There was a large variation in how much of the total maintenance performed was preventive, some had as much as 90 percent preventive maintenance, while the lowest only had 20 percent preventive. The issue is shown as a pie chart in Figure 4.1, each responding section is presented with its resulting percentage and also with the amount of responses the section got.

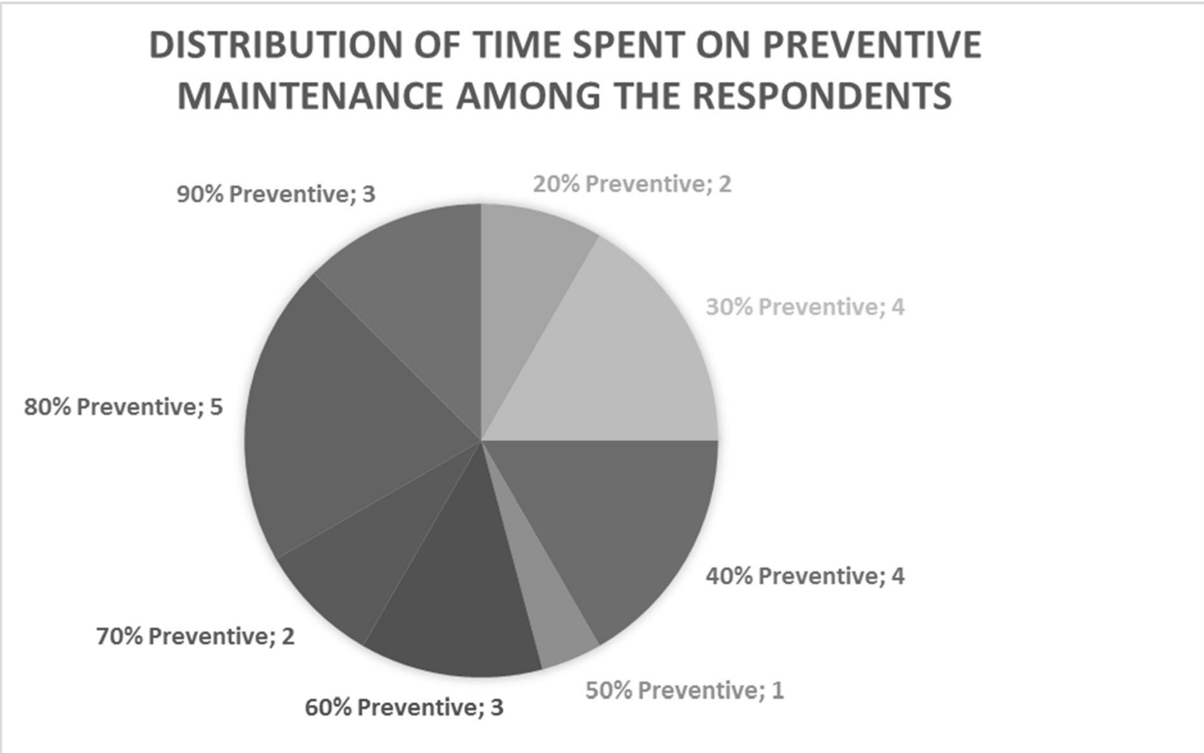

Figure 4.1 Preventive maintenance

There was also a noticeable variation regarding the possibility to determine the site's Overall Equipment Effectiveness (OEE). Despite a scattered result, the general response was that they were able to collect, compute and display the relevant information needed to calculate OEE. Therefore, it seems like most plants are working actively with OEE, and are able to conduct follow ups to determine the OEE's development over time.

Out of the twenty-four responses, eleven of the sites were using a CMMS, but none of those eleven sites were using the same system.

4.4.2 IT skills

The responses showed a varying degree of computer skills among operators, supervisors and maintenance personnel. While no respondent claimed that their personnel was completely unaccustomed to computers, there were not many plants claiming the direct opposite either. This indicates that the average computer knowledge within the group is good enough to handle the system available on a basic level.

More than one third of respondents rated it very important to have the possibility enter, retrieve and report relevant information in the maintenance system from a handheld device. Even though the majority of the surveyed found it important to have handheld devices, five rated it completely unnecessary.

4.4.3 Reactive maintenance

Only five of the polled answered that they did not conduct any maintenance at all before a work order was initiated. This means that most sites perform maintenance activities on the equipment before a work order is created. Four respondents even stated that they never created a work order before they started working on a maintenance task. Not a single respondent considered handling work orders as an unnoticeable part of a manager's workload. Furthermore, the responses were scattered over the remaining options, but it is clear that the work order handling is something that affect the manager's workday.

4.4.4 Autonomous maintenance

The operator's level of involvement with autonomous maintenance varied between the sites. Judging by the responses, shown in Figure 4.2, operators at most sites have some involvement with autonomous maintenance but not in the degree that is advocated by TPM. Just one of the sites stated that they had fully implemented the concept of autonomous maintenance.

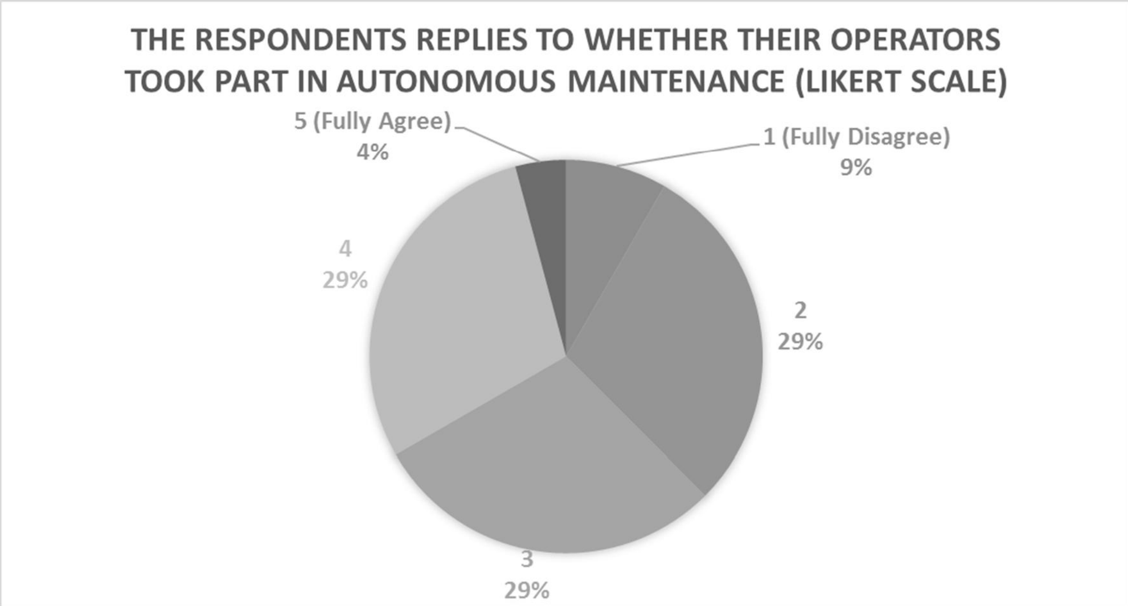

Figure 4.2 The operators are taking part in the autonomous maintenance

4.4.5 Preventive maintenance

Most respondents regarded the ability to generate preventive maintenance plans for a given time interval as one of the most important functions in a CMMS, twenty of the twenty-four polled rated it very important. In connection with the planning function, the respondents also highlighted the importance of a CMMS to have a function for scheduling maintenance.

A majority of the respondents revealed that the preventive maintenance was based on suggestions from the instruction books, rather than statistics from the equipment's maintenance history. No one fully disagreed with the statement, which indicates that no site uses only statistics to choose the length of the time intervals.

4.4.6 Follow-up on maintenance

OEE seems to be the most used performance indicator that the sites performed follow-ups on, a majority of the sites agreed or fully agreed on collecting and monitoring the information needed for OEE calculation. Just one of the sites fully disagreed to having the ability to calculate the site's OEE. Another performance index which can be used to evaluate the maintenance department is the ratio between preventive maintenance and reactive maintenance. Much like the statement regarding OEE, the majority of the polled agreed or fully agreed on continuously monitoring and following up on the distribution of reactive- and planned maintenance.

Performance indicator like MTBF (Mean Time Between Failure) and MTTR (Mean Time To Repair), which is closely connected with the maintenance department performance, were not used as much as the others performance indicators. The survey showed a large variation among the sites whether they measured and followed up the result of those two values or not. Another factor which could influenced the sites ability to perform follow ups is how easy it is for them to get relevant reports from the system. 12 of the respondents claimed it was easy or relatively easy to generate desired reports, while as many as 10 sites disagreed or fully disagree to the statement that it was easily done.

The importance of customisation of reports were expressed by several respondents. 11 of those who responded to the survey regarded it an important function, and 7 respondents stated that it was very important.

4.4.7 Personnel

There was no common view whether a CMMS should have a function that helped to store information about their internal and external personnel or not, this question received the lowest rating of all statements in the survey. It is important to connect this information with the fact that seventeen out of the twenty-four responding to the survey had a maintenance department consisting of 10 people or less. It is possible that the function for storing information about the employees felt unnecessary for those sites, since they only had a few members of the maintenance department. It is also worth to keep in mind that not every sites uses external resources on a regular basis.

4.4.8 Data gathering

Eighteen out of the twenty-four respondents agreed to that most or all maintenance activities performed are logged in the system, which indicates that the majority of the sites logged their maintenance activities in a large extent. Among the respondents were also two sites that did not log any activities at all. An area of interest in connection with this is that only seven of the polled fully agreed to the information reported in the work orders being accurate and relevant. So even though the majority of the plants reported to a large extent was the quality of the data gathered questionable.

A majority of the respondents seems to put emphasis on having the ability to automatically gather data in their CMMS system, which could get rid of the human error involved in reporting. Another way to improve data quality is to facilitate easy reporting, and there was a strong opinion among the respondents that the CMMS should be easy and fast for the user to enter and retrieve information.

4.4.9 Information handling

The survey responses showed that a majority of the sites stored the maintenance history of their machines, but the extent of it varied. Out of 24 respondents, did 21 rated it as important or very important. It seems like all sites have a way for storing history about maintenance jobs, either in a CMMS or in another IT-program.

The survey revealed that few of the sites had fully committed themselves to periodically reviewing the site's machine-related data. Another finding was that, even though many of them stored history about maintenance, few respondents thought that it was easy to find the maintenance costs per machine. Only eight respondents thought it was easy or relatively easy to find the maintenance costs, while the majority claimed the opposite. So even though many saved the maintenance history, the data saved seemed to miss some of the elements required to calculate costs.

4.4.10 Spare parts handling

Most plants had a spare part inventory that was being managed, but the degree of management of the inventory seemed to vary. Furthermore, the majority of the respondents did not take help from a CMMS system to determine which spare parts to keep in stock. On the other hand, it was considered rather important for a CMMS to have a function that could handle both the spare part inventory and related information. So even though it was not utilised by everyone today, there was a recognition of the potential benefits of doing so. There was no uniform view regarding the need of having the maintenance system linked to the site's purchasing platform.

4.4.11 CMMS questions and functionality

The responses regarding their current systems user-friendliness were mixed, the average was rather low, and only three of the polled fully agreed to their system being user-friendly. Another dimension of the user-friendliness is how complex the system is relative to the actual use of it. Out of the respondents only two sites used all function available, and the statement received the lowest rating of all statements in the survey.

4.4.12 Additional findings

Judging by the survey, the total cost of ownership of the CMMS is an important factor for many of the sites, with the majority of the sites considering it very important or important.

The survey highlighted the importance of having the CMMS available in the local language, the majority of the sites regarded it a very important criterion for a CMMS. Not as important, but still significant was the support available from the system supplier, which the majority of the respondents considered important or very important.

The interest regarding barcodes and NFC-tags was segmented, with about half of the respondents finding it important, and the rest paying little or no attention to it.

When asked to rate the importance of being able to customise the user interface, the general opinion among the respondents was that it was important. Out of the polled, only two sites who did not regard it important at all.

4.5 Main take away from survey

The most interesting results from the survey are presented in Table 4.2 and Table 4.3, for all responses please see appendix E.

Table 4.2 Key findings from the survey (I)

Key findings from the survey (I). *Responses to multiple choice questions regarding with statements about the sites current situation. Likert scale from 1 (fully disagree) to 5 (fully agree). The results presented is the average rating, with the standard deviation in parenthesis. Sample size of 24 plants.*	
Question statement current system	**Rating**
The maintenance history for each machine is stored.	4.42 (0.81)
TPM is an important part of our efficiency improving initiatives.	4.42 (0.86)
The preventive maintenance is based on the instruction books and experience rather than statistics.	4.13 (0.83)
The information needed to calculate the OEE of machines is collected and monitored.	4.08 (1.11)
All maintenance activities performed are logged in the system.	3.88 (1.66)
The CMMS system provides assistance in determining which spare parts to keep in stock.	2.77 (1.43)
The maintenance cost for each machine is easy to find.	2.50 (1.44)
The preventive maintenance is based on the instruction books and experience rather than statistics.	2.42 (1.35)

Table 4.3 Key findings from the survey (II)

Key findings from the survey (II). *Responses to multiple choice questions with statements regarding what the sites would consider important in a new CMMS. Likert scale from 1 (not at all important) to 5 (very important). The result is the average score, with standard deviation in parenthesis. Sample size of 24 plants.*	
Question Criteria	**Rating**
The system can generate a preventive maintenance plan for a given time interval.	4.83 (0.37)
It is easy and fast for the user to enter, retrieve, and report relevant information in the system.	4.71 (0.54)
The system can be used to hold equipment related data in an easy, accessible way. For example; machine type, ID-number, maintenance history, repair books, autonomous maintenance instructions, supplier details, position at plant and guarantee period.	4.50 (0.76)
The system is available in the local language.	4.46 (1.15)
The system has a function for scheduling recurring work orders and other tasks in a satisfying way.	4.29 (0.41)
The cost for using the software during its lifespan is as low as possible. Factors like purchase price, implementation costs, support and consulting services are taken into account.	4.13 (0.97)

The system is connected to, and capable of creating purchase orders in the purchasing platform.	4.04 (1.06)

5 Analysis

This chapter presents the analysis, which is based on the empirical data in combination with the frame of reference The chapter has been arranged under the same topics as in the empirical study. The chapter also includes an analysis of how a CMMS, on a theoretical level, can promote efficient maintenance operations. The chapter is then concluded by a summary of the analysis as bullet points.

5.1 Total productive maintenance

The empirical data shows a uniform view among the plants that TPM is an important part of their efficiency improvement initiatives. However, when comparing their way of working with TPM with the 8 pillars described by Suzuki (1994), there were only three of them that were frequently used; continuous improvement, planned- and autonomous maintenance. Out of them, the planned maintenance pillar was the predominant one, being worked with in some degree at all plants. The autonomous maintenance was in many cases a work in progress, with only some having routines on all machines.

Even though a company only should embrace only the pillars supporting the company goals (Suzuki, 1994), it is unlikely that out of 8 pillars, only one or two contributes towards the company goals. Instead, a more likely explanation is that it is a work-in-progress; as the TPM-directives come from group level as a whole concept it will take time for the plants to embrace all the parts of the initiative. This is most likely a general phenomenon in most industrial groups.

If a group were to standardise their CMMS and the choice was based entirely on the groups TPM-strategy, the system would most likely include most standard modules and potentially some more advance ones as well. However, as the plants are not at the same maturity level, they will not have any use for many of the functions. Smith and Hawkins (2004) points out that having an excessive amount of functions not being used can obstruct effective use of the more important functions. Consequently, when considering the standardisation of CMM-systems this difference in TPM-maturity has an important implication on the system choice; both the group strategy and the maturity of the plants must be considered in order to get an optimal solution.

5.2 Continuous improvement

This topic was only examined during the site visits, mainly because the way of working with continuous improvement requires answers of descriptive nature (i.e explaining a step-by-step process). There were various approaches among the plants regarding both how to identify problems and address them, but at least all had their own interpretation of it. So except for not employing cross-functional teams in some cases, the plants way of working was close to what is described in the frame of reference by Suzuki (2004). Considering the variety of approaches, it seemed like every plant had made their own interpretation the group guidelines, or had used an improvement approach already in place before the TPM-initiative was started.

Continuous improvement requires statistics to identify problem areas, for example machines with low OEE or long MTTR or short MTBF. Among the plants there were only one using data analysis to identify areas with improvement potential, but in that case it was the finance department analysing costs and not actual machine performance. In this case it would be better to determine on group level how to work with improvements, preferably in dialogue with the plants or by looking at how the plants work and deciding on a “best practice”. That approach can then be used as input into the CMMS evaluation process, yielding a system that supports it. This would provide the plants with a system that contains the tools needed to work according to best practice, thereby enabling the plants to fully embrace the focused improvement pillar.

5.3 Collaboration

There was no strong interest among the sites to share inventory with each other. It is likely to assume that the lack of interest is caused by the limited benefit a shared inventory has for each individual site, which makes it hard to see the bigger picture. According to David (2009), plants that are geographically close to each other could reduce their total inventory in stock if they were given the opportunity to view the inventory levels of the other sites, and then have the option to purchase it from the other site if the right part is available.

Several of the sites visited measured certain performance indexes and benchmarked their result with other sites with similar manufacturing processes within Trelleborg group. According to Peters (2006), benchmarking is a useful method that can be applied in a number of different ways in order to meet a range of requirements for improvements. Trelleborg group could extend their work with benchmarking and apply it on maintenance related processes as well. One of the group’s strengths is the large amount of manufacturing sites and all the joint knowledge that they possess. In order to take advantage of that knowledge and use that to improve the sites maintenance processes, increased maintenance experience sharing would be beneficial. However, according to the sites that would require better communication between the sites.

5.4 IT-skills

The empirical data showed varying levels of IT-knowledge throughout the plants. Looking at the site visits, the personnel at all plants seemed to have sufficient IT-knowledge to handle the present systems well, but the level of utilization of this knowledge varied. Only two plants had employed barcode scanning to simplify the data entry, and there was only one plant currently using tablets in their production. The survey showed the same pattern, but with less general IT-knowledge (averaging at 3.5). When asked about the possibility to use handheld devices in maintenance, it is likely to assume that the ones rating it low are not using it today, the ones in the middle are considering it and the ones rating it high are currently using such devices already.

As an IT-systems success is dependent on how the system is used (DeLone and McLean, 2003), this difference in knowledge will have serious implications on the use. If for example a standardised CMMS was chosen based solely on best-practice from one of the leading plants, the risk is that the system would be too advance for the less mature plants to use properly. They might end up with handheld devices they will not use, and a system that expects input from users that are not used to handling computers. Insufficient IT-knowledge increases the risk for input errors, and consequently endangering the absolute requirement of 100% data accuracy (Smith and Hawkins, 2004). This agrees with Kans (2008) approach, which also highlights the importance of evaluating the current IT-knowledge.

5.5 Autonomous maintenance

How a CMMS supports autonomous maintenance is not as intuitive as many of the other pillars, but it can simplify the maintenance related duties for the operators. This can be achieved by, for example: storing of checklists for all machines and keeping the lists easily accessible, storing of information about the machines, and it could also discover deviating patterns if control values are logged into the system. A CMMS could also help with tracking how much time the operators spends on autonomous maintenance, but even though it would be of value to management, being constantly timed would most likely not be appreciated by the operators. A solution to this dilemma could be to measure the time for performing a recurrent checklist a couple of times, and then use the average time spent.

5.6 Reactive maintenance

The term reactive maintenance refers to every unplanned maintenance action, and from a TPM point-of-view those actions should be analysed and, if they are recurring actions, be put in the preventive maintenance plan (Suzuki, 1994). This gathering is the main purpose of the work order module, but the usefulness of the data is highly dependent on all actions being reported with correct resource usage (man hours and spare parts). The empirical data showed that there were only a few plants that required a work order to be initiated before conducting any maintenance, consequently the rest of the has higher risk of violating Carneo and Novés (2006) requirement of 100% data accuracy.

There seemed to be a number of reasons why the work order system was not always used. Some of the plants visited initiated a repair request by contacting the maintenance staff by phone, and created a work order afterwards. This procedure seemed to be motivated by the fact that the person initiating the request got instant confirmation that the maintenance staff had acknowledged the issue. What sometimes ended up happening was that the issue was so acute that the maintenance staff came right away and fixed the problem, and in the process the creation of a work order was forgotten. Some plants mentioned that creating a work order in the system was time-consuming, and therefore the employees used the phone straight away instead of first creating a work order.

The question in this case is if having the maintenance staff manually receive every work order, which means them not being able to perform any repairs during that time, really facilitates them being as efficient as possible? Actually, having to disrupt their current assignment to answer the phone could be seen as one of the non-value-adding activities that TPM strive to reduce (Suzuki, 1994). However, this could possibly be the result of a conflict of interest between the production- and maintenance department; the production is eager to have their machine up and running and wants a verbal confirmation that repair is on its way, while maintenance wants to spend as much time as possible on core activities.

In a number of cases it was up to the maintenance manager to collect the work orders carried out, and then enter them into the maintenance system manually. This was a clear source of double-handling; first the maintenance staff had written down time and spare parts spent on the printed work order, and then the manager has to enter the same information into the system. Most sites agreed on that this manual handling of work orders was a notable part of a manager's workload. Considering the importance and challenge of having of well-maintained equipment, there are clearly better ways for a manager to contribute to the plant performance than just entering data.

When trying to decide on a standardised CMMS an important issue will be to find a system that will support the plants in attaining 100% data accuracy. But to do so, one must first understand how the plants are working today in order to determine how a CMMS can improve it. This agree with Kans (2008) approach, which also points out the importance of understanding how the system can support the current operations.

5.7 Preventive maintenance

The empirics showed that the majority of the plants were working with preventive maintenance plans, and highlighted the creation of preventive maintenance plans as the main purpose of a CMMS. The preventive maintenance module is indeed an important part of a standard CMMS (Bagadia, 2006), but it also contains a number of other modules that are important for achieving maintenance efficiency. The different modules are also interacting and exchanging information with each other (Carneo and Novés, 2006), so even if the PM-module is the one bringing the most notable change, the system should be considered in its entirety. For example, if there was no work order module, there would not be any way gather the data needed to determine statistic based PM-actions.

Even though almost all plants were utilising some kind of system to determine preventive maintenance actions, the majority of the input to those plans came from the instruction books. In a sense this is good, as the ones who built the equipment most likely knows when their machines need service or a change of components. However, that is given the machines are working the way they are designed for (i.e. a CNC machine processing metal). In the case of Trelleborg, they are in many situations machining different kinds of plastics with equipment designed for metal. Due to the nature of the production, there is a risk that maintenance is carried out on shorter intervals than what is actually needed, resulting in waste.

What was also seen in some of the plants was out-of-date equipment registers, violating the requirement of having all the facility's relevant data in the system, resulting in the PM-plans containing irrelevant tasks. This both cause confusion among the maintenance personnel and might even affect the prioritisation of other tasks that are actually relevant.

5.8 Follow-up

The focused improvement pillar of TPM puts great emphasis of continuously identifying and addressing issues in the production, but in order to know that the issue really has been resolved there needs to be ways to follow up on the actions. Follow-up on maintenance is in general an important part of assuring maintenance efficiency. However, the site visits showed only two out of six plants carrying out regular follow-ups, so why is it that not more plants are doing that? There seems to be a close connection to the information available, five out of six plants stated that it was hard to find good information to base the follow-up on. This links back to the work order module, which has the purpose of gathering maintenance data that then can be used in analyses and follow-ups (Suzuki, 1994). Considering that there were very few plants actually recording all maintenance data, it is not surprising that many plants feel that they lack relevant data needed to conduct follow-up on maintenance.

The difficulty of attaining relevant data cannot solely be blamed on the use of the work order module. Even if all the necessary data is being gathered, it is going to be up to the systems report function if you can analyse this data and put it to use. Some sites visited mentioned that they experienced that their report function was very limited, and could not produce the reports that they needed. So the ease of getting relevant reports seems to be dependent on two factors; the data gathered and the rigidity of the report function.

Even though none of the sites visited monitored OEE continuously, there was a clear trend among the surveyed sites to measure OEE. That metric is the core of TPM and one of the main indicators of how well the equipment is utilised (Suzuki, 1994), therefore measuring it should be key to all plants. Why are not all plants measuring it then? Is it a matter of maturity or are they lacking the tools necessary to do it? The empirics gave different explanations, some plants were not even considering measuring it, while others had tried but later stopped since it was too time-consuming. Over time the plants will mature, but to avoid them ending up in the same situation with the ones finding it too time-consuming, and at the same time helping those to start measuring OEE effectively, proper IT-support could be a solution.

OEE is not only an important measure and a good indicator of the equipment health; it is also directly affected by the work of the maintenance department. However, it does not provide any detail on the maintenance department's efficiency. For that purpose, there are two other frequently mentioned measures, MTTR (Mean Time To Repair) and MTBF (Mean Time Between Failure), that can be used to provide a better base for follow-up on maintenance performance. The empirics showed a varying degree of utilisation of these measures, and just as the OEE it most likely depends on two factors; maturity and system support. Either way they will over time, as the plants mature, end up being the same problem; lack up system support.

A third area of importance, which links back to TPM's goal of reducing a company's total cost of ownership for their equipment (Dale and Ireland, 2006) is the maintenance costs per machine. Out of the plants visited, none of them had an easy way of determining the maintenance costs per machine. The trend continued in the survey where it got the lowest averages of all questions (2.5), with a total of 8 agreeing or fully agreeing on that it was easy to find the maintenance costs for each machine. Once again the data available is closely linked to the work order module; if the time and spare parts consumed by each job is not always reported, it will be impossible to determine the real maintenance costs per machine. The survey results displayed a similar patter with 8 plants claiming it was easy or relatively easy to get the costs, which coincides with the responses that 8 plants did very little or no maintenance without a work order.

The different metrics mentioned above are important measures linked to maintenance, and should be continuously measured and followed-up on in order to ensure continuous improvement of operational efficiency (Jostes and Helms, 1994). However, as in the case of plant A, there can be other plant specific KPI's that can give additional input to their performance. These KPI's can be process specific and be better suited than OEE, MTTR, MTBF and costs per machine for diagnosing the causes for poor performance. These diagnostic measures can be useful in the continuous improvement work, and removing the ability to get generate this kind of reports in favour of focusing on OEE and similar measures can potentially be damaging. Many plants highlighted the importance of being able to produce customised reports from the system, so there are probably more plants that has their own performance measures that is not covered by their current system.

5.9 Personnel

Both the site visits and the survey showed a rather low interest in being able to store data such as competencies, cost per hour etc. regarding their internal and external resources. A possible reason behind this is that 22 out of 30 plants had a maintenance department consisting of 10 people or less. In that case the task of keeping track of the maintenance staff is probably not complex enough to require system support, and is therefore not motivating an investment in such a tool. However, what ends up happening if labour costs are not in the system is that the reporting of time spent on work orders cannot be directly converted to costs, consequently affecting the ability to follow up on maintenance costs per machine.

5.10 Data gathering

The previous topics has highlighted the importance of having high-quality data available, which in turn puts emphasis on having a good way of gathering it. Most of the plants involved in this study had a system for gathering maintenance information, either a CMMS or a paper-based system, which is one of the main requirements for attaining usable maintenance information (Smith and Hawkins, 2004). However, in many cases the data gathered (for example time spent on repairs) was not fully accurate and relevant, which violates the 100% data accuracy requirement. Additionally, all of the plants agreed to some degree that time spent on handling work orders was a notable part of a manager's workload, which can be interpreted as waste since all the information connected to a work order already has been noted once by the maintenance personnel.

To fully realise the benefits of TPM the data must be accurate, but judging by the responses the current systems for gathering data are not working good enough to support that. So there seems to be a need for either improved work order-processes, or a new system that can offer the plants an easy and user-friendly way to gather data with accuracy. As soon as a system gets complicated, people get an incitement to report later (affecting accuracy), or even refrain from reporting (loss of information) because it interferes with their main tasks too much. Therefore, the ease and user-friendliness is an important part since it both promotes accurate and complete information. The need for user friendliness was also highlighted as an important factor for a CMMS by several plants in the study.

There are more ways of promoting efficient use of the CMMS apart from having a user-friendly system, for example the use of handheld devices (tablets, smartphones etc.) and automating the gathering of machine information when it is possible. Handheld devices would mean that the maintenance personnel can carry the CMMS with them, allowing them to report when a job is started or finished in real-time, instead of the reporting them at the end of the day at a stationary computer, which the empirics show is the common practice. The real-time reporting would make it possible to track time spent on a job, improve the accuracy of the information entered and would allow the manager to have a clear view of the ongoing maintenance activities. However, like any other tool the usefulness of handheld devices will greatly diminish if the users lack the knowledge to use them properly. So even though handheld devices in many ways are more intuitive than computers, their usefulness will still be affected by the attitude towards- and knowledge in IT among the users. The IT-knowledge among the plants seemed to vary, and that can therefore be a factor affecting the usability in this case. Additionally, five plants showed no interest at all in handheld devices, which suggests that a standardised CMMS must be able to function effectively even without handheld devices.

Automated information gathering refers to machine parameters being monitored, allowing to measure downtime and register error codes. Two of the plants visited already had that type of automated gathering, but that was through their production system, which did not communicate with the CMMS. As different information linked to maintenance performance parameters is stored at different places, performing analyses in either the CMMS or the production system will not provide the whole picture. Many plants showed the interest in having automatic information gathering in the CMMS, but they might have the same issue with isolated data. Therefore, in order to facilitate effective automated information gathering and having all data in one place, it seems to be important that the CMMS can communicate with the other IT-systems present at a plant.

5.11 Information handling

They survey pointed out that the vast majority of the plants found the ability to be able to store equipment related information to be important, which corresponds with one of the basic functions associated with a CMMS (Peters, 2006); equipment management. Having that kind of information easily available has a great potential of improving maintenance efficiency; it reduces the time spent on looking through physical archives for instruction books, faster repairs by having maintenance history as reference and faster finding spare parts by having a part register for each machine. Handheld devices could potentially improve this efficiency even more by removing the need of moving to a stationary computer to connect to the CMMS.

However, digitally storing all equipment related information brings up one issue; the information stored must be in digital format. Looking at the plant visits, only half of the plants had the majority of the available information in digital format. The rest of them wanted to digitalise their documentation, but they lacked manpower to do so. So if a plant wants to fully utilise their CMMS's ability to increase the maintenance efficiency, they would need to be prepared to allocate some extra manpower to digitalising all information as a part of the investment.

As the data available is important for maintenance efficiency, it is equally important to keep the information updated so that maintenance decisions are not based on obsolete data. So starting to store the equipment data also comes with the responsibility of keeping it up to date. This was not the case at many plants, only one of the visited plants had, and only three surveyed fully agreed to having periodical reviews. As many plants placed importance on that the CMMS could provide suggestions in maintenance decisions, they will also have to be prepared to keep the data up to date in order to make well-inform decisions.

5.12 Spare parts handling

Although not being directly connected to any TPM-pillar, the inventory control module supports some of the core values of both TPM and TPS. For example, by managing the spare part inventory and logging the spare parts used in repairs, it is possible to determine which parts to keep in stock and which is better to order when it is needed. By doing so, the holding costs for spare parts can be minimised, which coincides with the TPS lemma to use as little resources as possible. A large part of TPM is reducing the total cost of ownership of the machines, and if the spare parts related to a machine is not managed, there is a large risk of generating holding costs that could have been avoided.

Two out of six plants visited kept track of their spare parts in the maintenance system, the same indications came from the survey, where a little over half of the asked were managing their spare part inventory. Traditionally, the spare parts inventory has been handled manually outside the plants inventory system by the maintenance staff, and it seems some plants are still doing it that way. Therefore, the explanation to why the inventory is not being managed at all plants is most likely linked to maturity, rather than feasibility. Another indicator of maturity can be seen in the survey; even though not all doing it today, almost all respondents have recognized the importance of spare part inventory control, and would consider an it important part of a CMMS.

In order to maximise the benefit of the inventory module, it must be able to provide correct inventory records, appropriate stock levels and item demand (Peters, 2006), which is heavily reliant on all spare parts used for all maintenance jobs is reported through a work order system. If the stock levels are not correct the maintenance staff might go searching for spare parts that was used a day earlier on another machine. Additionally, if the demand on the spare parts is not known, there is no good way to determine how much spare parts to keep in stock, and when to order new ones in order to get them before the stock runs out. The empirics showed that even though many plants managed their spare part inventory, not as many had the CMMS help them determine which spare parts to keep in stock (about 9 out of 30), which affects the benefit of the module. This is most likely connected to the extent which the work order module is used, where there were 9 plants who were strict, or almost strict in demanding a work order before performing maintenance. So even though the inventory module can bring great benefits, its usability is highly dependent on how prevalent the work order use is.

5.13 Current CMMS

It is very important to have a user-friendly system to achieve the 100% data accuracy mentioned by Smith and Hawkins (2009). However, only a few plants were fully agreeing on that their current system was user-friendly, so that is a potential explanation to the lack of data in the different areas. This also highlights the importance of having a user-friendly system in order to secure the data needed to fully realise the benefits of TPM.

User-friendliness can also relate to the complexity of the system, Smith and Hawkins (2009) mentions that having too many unused functions might obstruct the effective use of the

CMMS. The empirics showed that there were some unused functions in almost all plants, so most plants would potentially benefit from a CMMS more suitable for their needs.

What functions are needed or not is a complex question, first of all it requires input from all the stakeholders at the plant (Kans, 2009) in order to at least consider the needs of each. Out of the site visits, the maintenance department (or even just the manager) had made the system choice. This is most likely the case in the majority of the plants, and can be a part of the explanation why few of the sites maintenance systems are performing at top level.

5.14 Supplier

In a multi-national company there is always a risk that the blue collar staff only knows the local language, and that was also seemed to be the case a number of the surveyed plants; 17 out of 24 viewed it as a very important aspect of a CMMS. To ensure that a system can be used properly by everyone that should be able to use it, language support seems like a must.

A well-functioning CMMS is a powerful tool in the quest of realising the full benefits of TPM. Among other things, the CMMS helps in the quest of minimizing downtime, but what happens if the CMMS breaks down? In many of the previous topics the benefits of incorporating the CMMS more in the maintenance work has been highlighted, but that also brings the risk of not being able to work without it. Almost all plants were currently using a CMMS, and they seem to agree on the importance of the system for the maintenance operations, as the majority rated the ability to reach system support high.

5.15 Purchasing

Despite the varying opinion regarding the importance of connecting the CMMS and the purchasing system, that connection could be beneficial to the plants by making the procurement more efficient. Examples of such efficiency improving functions are: automatically generated suggestions for purchasing orders, efficient execution of purchasing orders and that it shares the information from the purchasing activity with the other modules in the CMMS.

A number of sites visited either did not use, or did not have any purchasing function in their current CMMS, and did not experience any need for such a function either. It is likely to assume that the same applies to the sites answering the survey. This is a likely explanation to the scattered answers regarding the importance of having the CMMS connect to the purchasing platform.

How well a purchasing module is functioning relies heavily on how utilised the CMMS is in general. For example, the spare part inventory module must be in order to know which parts to order, and the work order module must be used to report spare part usage in order to keep the stock levels up to date. If that is not in place, then the purchasing module will lose much of its purpose, since there will be no correct stock levels to base the re-orders on.

5.16 System characteristics

The ability to customise the CMMS was not regarded as a key requirement among the survey respondents, but that is most likely as they see it from a single plant point-of-view. From a group perspective things are a bit different; throughout the analysis, many differences in maturity has been shown between the plants, and these are the most highly rated plants in terms of maintenance systems. In the case of a standardisation the system should be able to work reasonably well with all plants in the group, while avoiding having too many unused or too complex functions. That has a strong implication that, in order to secure a reasonably good fit with all plants, the CMMS should be able to be customised to hide unused functions, choose data to gather with work orders or even disable parts of certain functions.

The total cost of ownership for the maintenance system was seen as one of the key factors in the survey, and obviously this is an important, measurable factor when comparing systems. However, as this is a system that is designed to increase efficiency, resulting in lowering costs, and its ability to achieve this is highly dependent on its functionality, the highest priority should be the organisational fit. But naturally, if two similar systems both have comparable functionality, cost should be an important decider.

5.17 Maintenance procedures

The site visits revealed that the maintenance procedures varied throughout the plants, but all that were reporting work orders something in common; double-handling of information. In every case, the finishing of a work order was done later than the actual repair. This means that if job-related information like time spent and spare parts used are to be reported, it has to be noted in some way (for example by pen and paper) until the work order is finished in the system. In the most extreme cases, it is up to the maintenance manager to take care of these notes and report into the maintenance system, which according to the empirical data, is quite time consuming. This creates an interesting paradox; they are working with autonomous maintenance in order to give maintenance personnel more time to spend on more advance tasks, but still they have managers who spend a noteworthy amount of time performing trivial data entry.

In theory, how could a modern CMMS get rid of this waste, and improve the maintenance procedures at the plants? Let’s start from one of the processes described in the empirical data chapter, the referred process is visualised below in Figure 5.1

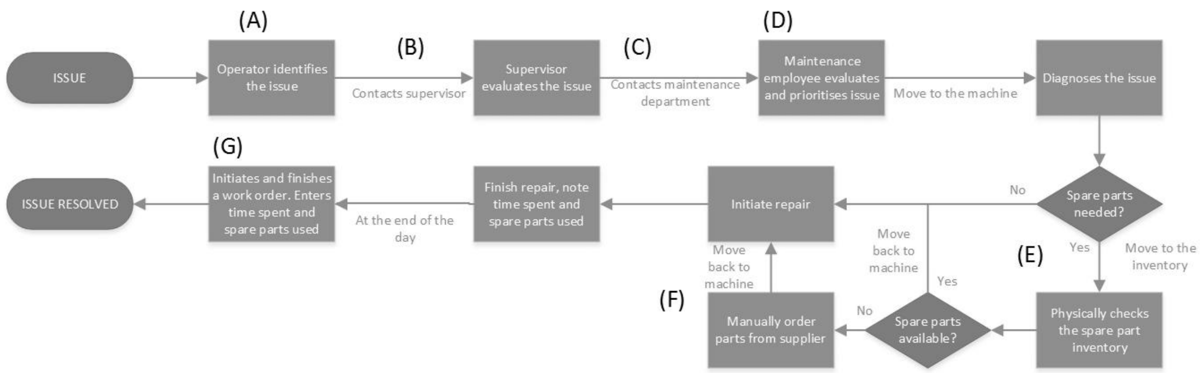

Figure 5.1 Process cart over a generic maintenance procedure for the sites within Trelleborg group. The letters A-G indicates points of improvements.

(A) If the issue identification requires the operator to identify it in order to solve it, there is a risk that there is an issue affecting quality, but that it is not identified right away. A modern CMMS monitoring certain parameters linked to quality deficiencies could identify such issues much earlier, and automatically generate a corresponding work order.

(B) & (C) As the procedure is right now, both the supervisor and, in turn, the maintenance personnel have to be contacted by either phone or by finding them. But what if these key actors are unavailable at the moment? If it is just a smaller issue, there is a risk that the operator will start doing something else and forget about it, or perhaps go home for the day, leaving the issue unattended for a longer period of time. For the maintenance personnel, to get phone calls every time someone wants to report an issue will also consume their time, giving them less time to spend on advance maintenance tasks. By utilising a work order system in a modern CMMS, that is easy to use for operators, the issue can be reported at once. Furthermore, the maintenance staff does not have to take care of all the issues by phone, thereby giving them more time to spend on maintenance.

(D) The evaluation and prioritisation of an issue can potentially be hard to do over phone, especially as the operator has limited knowledge in the machines mechanics. A modern CMMS would allow the attachment of pictures and informative text to a work order, allowing the maintenance personnel to make their own perception of the issue. Additionally, in a plant with over 500 machines, the maintenance staff can know exactly which machine that the request is referring to, as well as its location. Work orders tied to prioritised machines will also automatically be sent to the top of the work order list.

(E) Once the maintenance technician has diagnosed the issue, and realised that spare parts are needed, the next step typically to go to the spare part inventory and physically check if the spare part is available. If the part is not available, there is nothing more to do than ordering a new part, but then time has been wasted physically looking for a spare part. By having a CMMS handle the spare part stock, the maintenance staff could check the inventory level from anywhere in the plant, avoiding the walk back to the inventory, and take appropriate actions.

(F) In most cases, the maintenance department handled the spare part procurement manually, by calling the supplier or visiting their homepage. By using a purchasing module that procurement could be done with a few clicks, and then be sent to the supplier.

(G) At every site visited, the work order was not finished at the same time as the repair, leading to the double-handling of information mentioned before. Additionally, there is also a higher risk of inaccurate data when the reporting is done later. What ends up happening when nothing is reported in real-time is also that much of the data available in the maintenance system, such as current work orders and spare parts in stock, is not accurate. By using a modern CMMS that is available throughout the plant the reporting can be done right when the job is finished, ensuring data quality, real-time information and eliminating the double handling of information.

5.18 Analysis summary

Below are a summary, see Table 5.1, which contains a summary over the key finding from the analysis chapter.

Table 5.1 Key findings from the analysis chapter.

Total productive maintenance	• The plants are working their way towards embracing all the pillars of the TPM-concept stated by the group • The CMMS system choice must take both the groups guidelines and plants current situation into consideration
Continuous improvement	• Every plant had their own way of working with the TPM pillar continuous improvement • Only one plant employing data analysis to identify improvement areas • Developing "best practices" for continuous improvements, and choosing a system based on them would give all plants the possibility to work according to them
Collaboration	• It might be difficult for the individual sites to see the benefit of having a shared inventory, but would benefit the group • Having the plants using the same system and measuring the same performance indexes would create the possibility for maintenance benchmarking • Would be beneficial for the group to promote more communication between maintenance departments
IT-skills	• The level of IT-knowledge at the sites has a large impact on how well a CMMS can be utilised and how advance it can be • A standardised CMMS must be compatible with all different levels of IT-knowledge within the group
Autonomous maintenance	• A CMMS could support an operator with the autonomous maintenance tasks by storing checklist and other useful information • A CMMS could assist in tracking how much time the operators spend on autonomous maintenance
Reactive maintenance	• Each site needs a system that enables them to record all maintenance activities with accuracy • A filled-in work order should be the perquisite for the maintenance department to address an issue. • Strict work order usage promotes both data quality and the maintenance department efficiency. • Physical notes should not be used in combination with a CMMS, as it is a clear source of waste
Preventive maintenance	• Many sites are creating waste by not continuously reviewing their PM plans • The sites would benefit from using maintenance history to update their PM intervals
Follow-up	• The lack of relevant information to perform follow-ups on is a direct consequence of the insufficient collection of maintenance data • The follow-ups that can be performed are also limited by the system's ability to generate relevant reports

	• The lack of OEE calculation at many sites can be caused by lacking system support or how far the plants have gotten in their embrace of TPM
Personnel	• Small maintenance departments could explain the lack of interest in system support for handling maintenance personnel • Lack of labour cost information affected the ability to determine maintenance costs per machine
Data gathering	• Complicated processes for information gathering negatively affects the quality of the gathered data • Handheld devices can improve maintenance efficiency, but requires proper utilisation • The CMMS at a plant should be able to communicate with other IT-systems in order to facilitate automatic data gathering
Information handling	• Having the machine related information in digital form can make maintenance operations more efficient • Handheld devices can improve the efficiency further by allowing access to the information anywhere in the plant • Some sites will have to digitalize their information in order to achieve the benefits • System data has to be kept up to date in order to be useful in maintenance decisions
Spare parts handling	• A CMMS could optimise the spare part inventory by using statistics from the maintenance history • A low maturity level is a contributing factor to why spare part inventory is not always managed • The spare part inventory can only be optimised if a WO module is used properly
Current CMMS	• The systems user-friendliness affects the accuracy of the gathered data • Too many unused functions can obstruct effective CMMS use • To determine which functions that are needed, input from all stakeholders is needed
Supplier	• The system must be available in a language that the users can understand • Building maintenance processes around a CMMS puts higher requirements on system support
Purchasing	• Purchasing module makes the process of restocking spare parts more efficient • The benefit of the module relies much on how utilized the CMMS is in general, and especially the spare part inventory module
System characteristics	• The group could benefit from a customisable CMMS to achieve a better operational fit • Hard to value the total cost of ownership against efficiency improvement
Site characteristic	• Double handling of information is created when work orders are handled with physical notes before they are entered into a CMMS. This is a clear waste of time.

6 Need identification process

This chapter presents the approach for determining the CMMS needs of a group with motivations for each step based on the analysis.

Based on the information gathered from the plants throughout Trelleborg in combination current theory on determining CMMS requirements at a single plant, a process for determining the CMMS requirements in an industrial group was developed. This process is aimed towards both ensuring that all relevant data is gathered, and converting that data from statements and observations into a structured need specification that can be used when evaluating which CMM-system to standardise. The process in its entirety can be seen in figure 6.1, and the different parts of this step-by-step process will be covered in this chapter. For instructions on how to apply the process see appendix I.

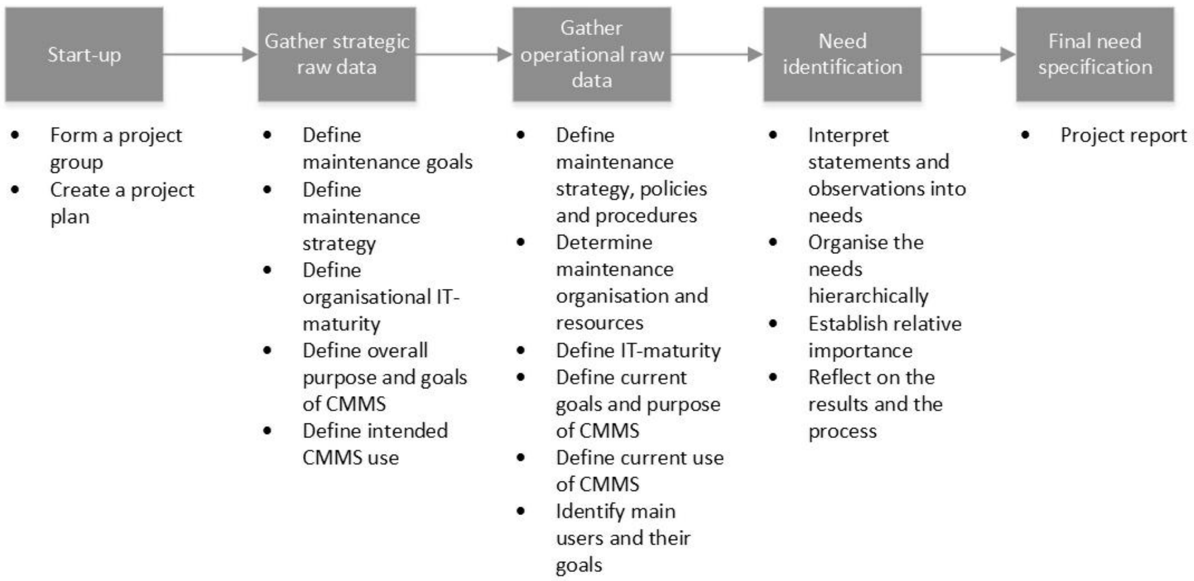

Figure 6.1 Generic process description for how to find a global industry's needs of a CMMS.

The philosophy of the process originated from Kans (2008) application of DeLone and McLeans (2003) model in a maintenance management context, and is that "in order for a CMMS to be successful it must fit both a group's present- and future situation". In line with this philosophy the data gathering starts at group level, as it is here the overall strategies are set and many of the efficient improvement initiatives are initiated, which dictates future of the maintenance operations. This is also done first in order for the project group to get an understanding of where the maintenance operations are heading, which creates a better context when gathering the operational data. Subsequently, data from the sites is gathered as their needs and opinions are just as important as the groups. If the system does not support the way of working at the plants today the risk is that instead of improving the efficiency, it will decrease it. Likewise, as the maintenance operations at the sites matures and the group initiatives are embraced more, the system must be able to support that as well.

6.1 Start-up

The process should be initiated at group level when evaluating the possibility of finding a standardised CMMS to be used within an industrial group. However, this process will not give a simple answer to the question, but will assist in this task by determining the needs that such a system should satisfy. To create a solid foundation for proceeding steps, with the goal of ensuring the best possible output, a start-up phase was incorporated. This initial step was something that the current approaches lacked.

6.1.1 Form a project group

Just as Ulrich and Eppinger (2012) highlights in their product development process, such processes are always best carried out in teams. Both because of the workload involved in data gathering is extensive, but also because different people interprets statements in different ways, which facilitates a more comprehensive need identification. Therefore, the project group aims to involve people with different knowledge.

6.1.2 Create a project plan

To guide the project execution and control, a project plan should be created. As a crucial part of the need identification process is the visiting of production plants, these visits needs to be booked as soon as possible in order to ensure the visits can be done according to plan. Because if they are not, there is a risk that the whole project is delayed.

6.2 Gather strategic raw data

When choosing a standardised CMMS system, it is a long-term commitment, but an organisation that wants to stay competitive has to constantly improve their way of working. Therefore, it is crucial not to base the choice on where the group is today, but rather where the group wants to be tomorrow. The long-term goals are reflected by the strategy, which is dictated on group level, therefore the strategy should be the base for the need identification.

Initiating the process with the strategic data gathering is also has the benefit of creating a better comprehension of the group before visiting the plants, which in turn facilitates a deeper understanding of the plant characteristics. The strategy can also be a good inspiration for questions to use in the data gathering.

6.2.1 Define maintenance goals

Maintenance is often not a strategic function (Peters, 2009), and therefore there are often no strategic goals stated. The purpose of a CMMS is to support maintenance, but to fully understand how that is done, one must first understand what the goals are in order to know how to reach them. Maintenance is a support function intended to support the operations, so by deriving maintenance goals from the overall group strategy, this connection can be assured. This step is essentially step 1 in Kans' procedure, but the target for the step was changed from a single plant to an industrial group.

6.2.2 Define maintenance strategy

With the goals in place, a strategy has to be determined in order to know how to work with maintenance to reach its goals, and ultimately supporting the organisational goals (Kans, 2008). Supporting this strategy should be the reason for standardising a CMMS, otherwise it will be difficult to take maintenance from a tactical to a strategic level. As this step is a natural successor to the maintenance goals step, this step is similar to the step 3 in Kans' procedure, but modified for a group setting.

6.2.3 Define organisational IT-landscape

As mentioned in the analysis, the ability for the CMMS to connect to other IT-systems (especially ERP) was an important part of making the reporting more efficient, therefore it is of interest to determine which systems that are present in the group so that the ability to connect to those can be evaluated. The IT-infrastructure can also be an important issue, as the CMMS needs to be hosted somehow, either locally, in the cloud or by a supplier. This step is incorporated due to the added IT-complexity that comes with working in a group setting, and is not mentioned in any published processes.

6.2.4 Define overall purpose and goals of a CMMS

This step is aimed towards assuring efficient maintenance operations, and does so by defining which expectations the group has from a CMMS. The expectations are derived from the maintenance strategy, and are an important part of ensuring that the system fits the organisation (Smith and Hawkins, 2004). This step is motivated by other sources than Kans', but it is also quite similar to step 7 and 8 of her procedure. However, it has been moved up much earlier in the process compared to that procedure, and has been aimed towards CMMS only.

6.2.5 Intended use

As mentioned by DeLone and McLean (2003), one of the contributing factors to IT-system success is the system use, therefore there has to be a clear plan on how to use the system in order to ensure a successful standardisation. The system should only be used to support the maintenance goals, and should therefore be derived from them. This step is a natural successor of the previous step, both in this process and in Kans' procedure, but it has in this process been incorporated on group level rather than in the single plant setting.

6.3 Gather operational raw data

The purpose of this phase is to gather information from the plants on their way of working with maintenance today, and to get their input on their needs of a CMMS. It will require data gathering from a number of plants in the group, either by visiting them (recommended) or by sending out a survey. The preferable option, given there is enough time, is to conduct site visits as it facilitates better information gathering as it allows for observations as well. When being on site there is a much better chance of identifying latent needs, that the plants perhaps have, but have a hard time to express. As this part of the process is designed to create an understanding of how maintenance is carried out at the plants and the nature of the maintenance organisations, the goal is identical to the initial phase of Kans' procedure. Therefore, the steps in this part of the process are also based on the steps presented in Kans' procedure.

6.3.1 Define maintenance strategies, policies and procedures

By determining the maintenance strategies, policies and procedures at the plants, their way of working with maintenance can be understood. The importance of doing so has been highlighted in several analysis topics (TPM, reactive maintenance, follow-up, system characteristics), and much of the need identification originates from observing and analysing the current way of working. For example, while the managers need 100% data accuracy for analyses, the maintenance staff and operators just wants to get the machine up and running as fast as possible, the CMMS must be used to satisfy both wishes as good as possible.

This step also provides the possibility to identify possible improvements that can be realised by having a standardised CMMS. Additionally, assessing the way of working at a plant is an important determinant of the maintenance maturity level, which can be valuable input for choosing which plants to initiate a pilot at.

Having mapped these factors also adds some context to the proceeding steps, as both the purpose and goals of CMMS and identification of main users are dependent on how the maintenance organisation works.

6.3.2 Define maintenance organisation and resources

The analysis showed that maintenance organisation and its resources have some implications on the CMMS needs that requires to be taken into consideration, mainly connected to the scheduling, personnel data and system characteristics. Depending on the organisational set-up there are different implications regarding the needs, for example the organisations size affects the need for the support from the scheduling module. Additionally, if external personnel are frequently present at the site, the CMMS must support them creating and finishing work orders.

6.3.3 Define IT-maturity

As the purpose of the process is to finding a fitting CMM-system, the IT-maturity of a plant is a major delimiter when it comes to what benefits can be achieved with such a system. The analysis highlighted the importance of having 100% data accuracy in the data entered in the system, and the risk for input errors if the system is too complex for the users.

6.3.4 Define current purpose and goals of the CMMS

In the process of determining the needs, the clearest connection to the plant needs is the purpose and goals of the CMMS as they clearly state what they currently expect the system to do. If their current system was to be changed for a new, standardised one, the new system should at least fulfil the purpose and goals, or else there is a risk it won't fit the organisation. Another benefit of stating the goals and purpose is that the current system can be evaluated in regard to those, consequently enabling an assessment of how well the current system is working. In the cases the system is working well, those systems that can be of interest in the following procurement process. In the cases it is not working well, the reasons why it doesn't can be evaluated in order to avoid dysfunctions in the standardised system.

6.3.5 Identify main users and determine their goals

In the analysis, proper use was highlighted several times as one of the main requirements to be able to fully realise the benefits of a CMMS. Therefore, gathering input from the users is an important part of ensuring that the standardised system reaches its potential. Doing so also has the possibility to highlight needs that are not covered in the maintenance strategy. An example is the need for user-friendliness that was emphasised on during both the site visits and in the survey, but which could not be interpreted from the general strategy.

6.4 Need elicitation

During this thesis, a lot of empiric data has been gathered in different forms, but in that form the information is not structured enough to be useful in a procurement process. Therefore, the need of an approach of turning statements and observations into something structured was highlighted. Moreover, the relative importance of the different needs has to be determined as well in order to support trade-off decisions. This part of the process is a further development of the final step in Kans' process; "Identify required IT functionality and characteristics to meet maintenance business demands", which offers little guidance on how to actually turn the gathered data into something useful. All steps in this part are inspired by Ulrich and Eppinger's (2012) product development process, but applied in a system choice situation.

6.4.1 Interpret statements and observations into needs

At this point the data gathered is a mix of statements, observations and survey responses, all expressed in different ways. As shown in the analysis, much of this data has implications regarding the CMMS system, either explicit or latent. However, in order for the data to be useful, it must be structured first. By interpreting the data into need statements, it is converted to a common form, which then enables the data to be grouped and its relative importance estimated.

6.4.2 Group the needs

As the previous step can result in a high number of needs (50-300), grouping them up into categories is crucial to create a structure that is easy to work with. Even though the questions in the interview guide, had been categorised (while the survey was not), the answers sometimes yielded implications regarding needs in other categories. For example, the questions under the follow-up category highlighted the importance of relevant and accurate information gathering, which is another category. Therefore, the need statements should be grouped without regard to any previous categorisations done in the data gathering.

Looking at the analysis, there are cases where two different statements (in the data gathering and information handling category) expresses the same need, for example the support for handheld devices. In order to avoid making the need elicitation unnecessarily tedious, the removal of repeated statements is an important part of this step.

6.4.3 Establish relative importance

At this point, a lot of need statements has been interpreted and grouped. However, the importance of a need cannot be determined based on the expression of it. As the goal of this section is to identify needs from the sites that are to be consider in the choice of a standardised CMMS, actions must be taken to determine which needs that are important to the sites, and which are not.

6.4.4 Reflect on the results and the process

The needs identified in the previous steps will be key input to the final need specification, and to ensure quality it is important to take a step back and reflect on the process and its results. What statements are gathered, which then can be interpreted into needs, is somewhat dependent on what questions are asked in the interviews or surveys. Therefore, it is important to use the knowledge in the team to assess if there are any needs missing that should be present.

Additionally, if a CMMS is to be standardised, not all plants can implement it at the same time. It must start with adopting the system at a number of pilot plants and then expanding it successively. At this point of the process a lot of data has been gathered from each plant, so now it should be a good time to use that data to identify plants that are interesting to have as pilot plants.

6.5 Final need specification

Up until now the strategic- and operational needs has been examined in isolation, and in order to achieve organisational fit a CMMS must satisfy the needs from both of these dimensions. Most of the groups needs are also expressed as how the system is supposed to be used, so that also needs to be converted to need statements to ensure everything is in the same format. Therefore, this final step has been designed to compile these two aspects into a final specification, representing the combined group CMMS needs.

7 Conclusion

To conclude the thesis, this chapter starts with a short presentation of the answers to the research questions. It then moves on to explaining how this thesis has contributed to theory before providing recommendations for the case company. Then, suggestions for future research are presented. Lastly, the limitations of the thesis are discussed.

7.1 Answers to research questions

7.1.1 What are important factors to consider in the standardisation of CMMS in an industrial group?

The analysis chapter highlighted a number of factors in different areas that seems to affect the success of a CMMS, see Figure 7.1 and Table 7.1. To conclude this research, the different factors have been summarised into a number of criteria that are important to evaluate when selecting a CMMS. The approach presented in chapter 6 is a tool designed to evaluate these criteria.

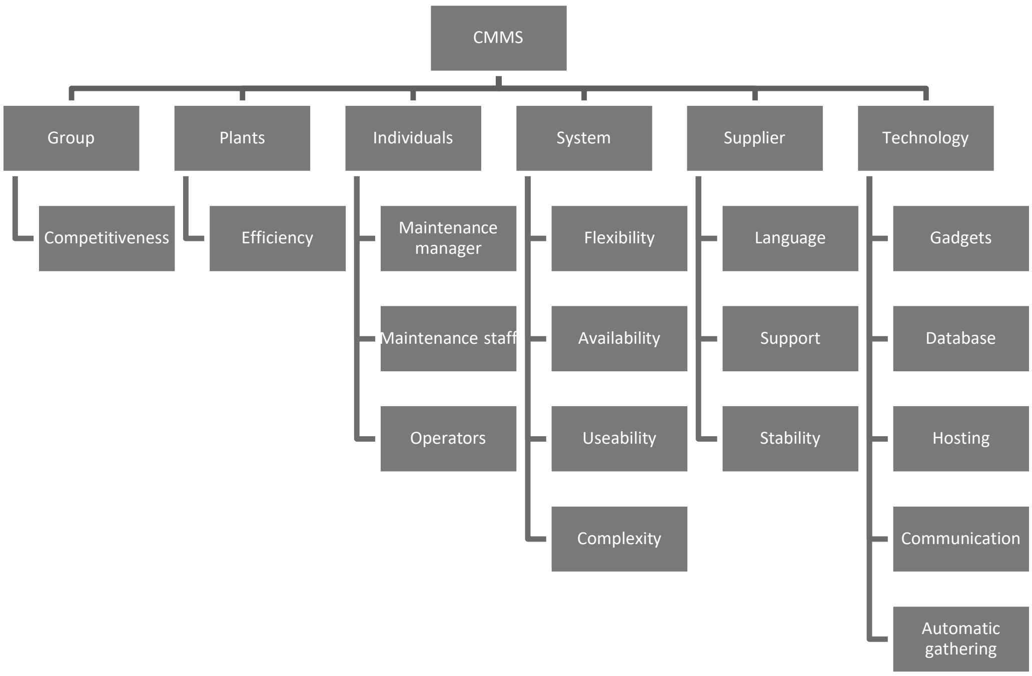

Figure 7.1 Chart over important criteria**.**

Table 7.1 List over the important criteria and explanation.

Group	
Competitiveness	How well does the system support the group being competitive in their business environment?
Plants	
Efficiency	How well does the system support the plants in being more efficient in their production operations?
Individuals	
Maintenance manager	How well does the system support the maintenance

	managers in daily management and maintenance decisions?
Maintenance staff	How well does the system support efficient equipment maintenance, and maximise time spent on repairs?
Operators	How well do the system handle maintenance requests, and how well does it support the operators' daily tasks?
System	
Flexibility	Is the system flexible enough to fit the different plants way of working?
Availability	Does the system support easy access throughout the plants, and how reliable is it?
Usability	How user-friendly is the system?
Complexity	What kind of knowledge is needed to operate the system, and can the complexity be reduced?
Supplier	
Language	Is the system available in the languages needed in the group?
Support	How easy is it to get remote and local system support, and is it available in the languages needed?
Technology	
Gadgets	What kind of tools can be used to so simplify interaction with the system?
Database	What kind of database model does the system use?
Hosting	What are the hosting possibilities for the system?
Communication	Is the system able to interact with the other IT-systems present at the production sites?
Automatic gathering	What kind of data can be automatically gathered by the system, and how is it gathered?

7.1.2 How can an industrial group determine their needs from a CMMS in a structured way?

The developed approach was fully presented in chapter 6. It was inspired by the single-site approach developed by Kans (2008), but reworked and modified to incorporate the factors identified in Research Question 1**.** Additionally, to provide the user a firm guidance all the way to a need specification, Ulrich and Eppinger's (2012) structured process for identifying needs was incorporated in the approach. The approach consists of five main steps, which in turn contains a number of activities, which are presented in figure 7.2.

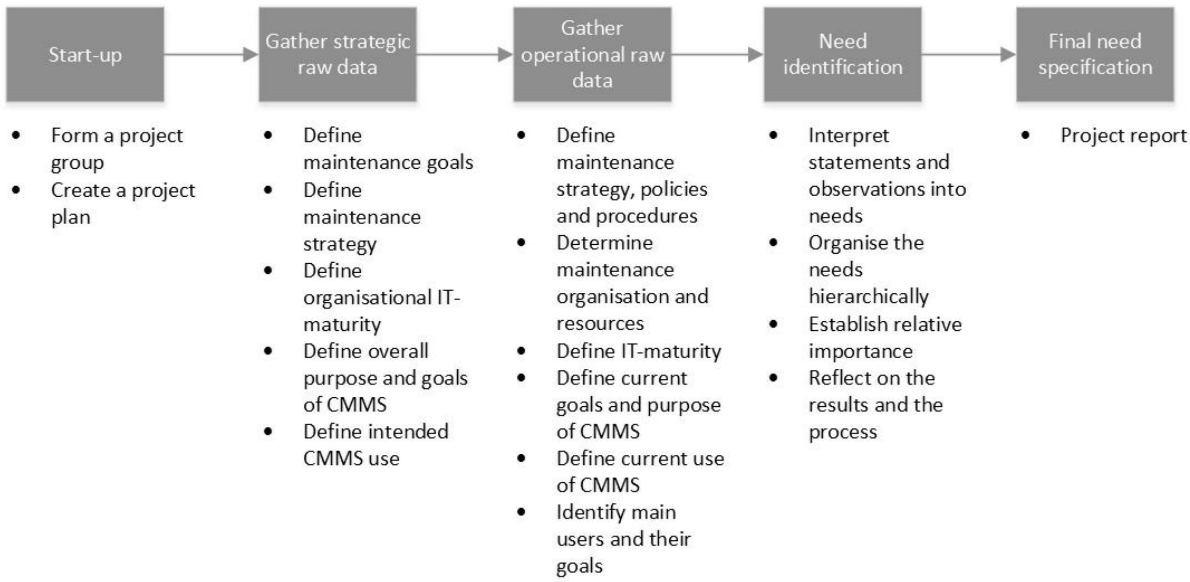

Figure 7.2 Need identification process

Start Up: The purpose of the first step is to create a foundation for the proceeding steps by ensuring that the necessary perquisites for a successful project are in place. Since the outcome of the project could potentially affect the whole organisation, the project should be an initiative at group level. In order to receive as comprehensive output as possible from the process, a team should be formed by people from different functions and levels. Having a team is necessary since there will be a lot of work involved in the gathering and analysis of data, while the purpose of the diversity is to promote input from different points of view. Once the team is formed a project plan should be formed to promote a structured way of working, and to ensure that necessary meetings and site visits are booked as soon as possible.

Gathering of strategical raw data: In order to stay competitive, an industrial group must constantly evolve and improve, and as a CMM-systems success is closely linked to how well it fits the organisation, the settings it must fit is also constantly changing. The direction of this development is dictated by the strategy, and that is why this step is focused on determining what implications this strategy has on maintenance operations. The initial part of this step is to, if not already stated, to derive maintenance goals and a strategy to fulfil them based on the organisational goals. Based on the strategy, the overall purpose of using a CMMS can be derived. This purpose should then, in combination with the team's knowledge on CMMS, be used to determine how the intended use of a CMMS. Another important factor to evaluate is the organisational IT-maturity, since it will affect both the system choice in terms of both hosting possibilities and what other systems the CMMS has to be able to interact with.

Gather operational raw data: This step covers data gathering from another important dimension for achieving organisational fit, namely the plants current way of working. This step should be conducted at as many plants as possible in order to gather enough data to be considered representative for the group. The step begins with the definition of the maintenance strategy, policies and procedures as well as the maintenance organisation and its resources, with the purpose of understanding how maintenance is handled at each plant. It then moves on to reviewing the goals and purpose of their current CMMS, as well as how they use their system today. Next, the different users of a system should be identified and interviewed, as they might have different goals of using the system, and different perception of it. Lastly, to determine the applicability of a modern CMMS the general IT-knowledge at the plants must also be mapped.

Need identification: When all the information is gathered, the next step is the need identification phase which is about creating structure in the mix of statements, observations and possibly survey responses, all expressed in different ways, collected in the previous steps. The initial step is to interpret the gathered data into need statements, and the purpose of that is to get all data in a common form. A need statement is expressed as an unbiased statement about the system, for example; "the system supports handheld devices". Since it is not unusual to get between 50-300 needs, the next step is to consolidate the needs that are similar into larger groups based on topics, at this point redundant statements should be removed. Up until now, all need statements have been equally important, but for them to be useful in a CMMS evaluation process, the relative importance of the needs must be established. Finally, the team should reflect on the result, which will act as a final check to promote the quality of the result.

Final need specification: Until this step the strategic and the operational needs have been separated from each other, but in order it achieve a good organisational fit both of these dimensions has to be taken into consideration when determining the requirements on a CMMS. The strategic needs are at this point expressed as intended uses of the system, but that also needs to be converted into need statements to ensure everything is in the same format. Therefore, the final step has been designed to combine the both aspects into a final specification, representing the requirements from the whole group on a standardised CMMS.

The approach was reviewed by the project supervisor at Trelleborg Group, who considered both the structure and the steps relevant in their case. When applied on Trelleborg Group the approach yielded relevant results and the different steps were following each other in a structured way. The result is showed in Appendix J. Despite the obvious bias involved when the developers are testing their own work, much of the approach is employing the same logic as recognised models like DeLone and McLean (2003) and Ulrich and Eppinger (2012), and the approach could therefore be regarded as structured.

7.1.3 What are Trelleborg's requirements from a CMM-system?

By applying the step-by-step approach developed during this study, see figure 7.2, on the case company Trelleborg, the group's needs from a standardised CMMS was determined. The process resulted a number of needs, see appendix J, which were arranged into 12 groups. These groups are presented below together with a description of its contents.

Analysis: The system should be able to support maintenance decisions by creating suggestions based on the gathered maintenance data as well as assist in the evaluation of maintenance performance. Additionally, the system should provide fast and easy ways to customise reports and to analyse data in general.

Availability: This group addresses the need for having a CMMS that is available anywhere in the plant, and the importance of that the system is responsive. The need of support for multiple users is also highlighted.

Connectivity: The only need in this group is the system's ability to communicate with other IT-systems in the plant.

Continuous improvements: The system should be able to track a number of performance indicators such as OEE, unplanned machine stops, MTBF and MTTR and display chosen parameters in real-time. Additionally, it should be possible to determine the maintenance costs per machine, and for operators to report improvement suggestions through the system interface.

Data gathering: The needs connected to data gathering had three different characteristics. Most of the needs was included in the first category, and related to making it easier for the user to enter, receive and process data. The second category of needs focused on achieving and maintaining high maintenance data quality. The third category of needs highlighted the need of being able to customise the layout and input variables in the reporting function.

Information handling: The information handling group highlights the need of having a system that can store machine related information in a way that is easy access. Several of the needs specify what kind of data that should be stored, such as digital documents, maintenance history, autonomous maintenance instructions etc. There is also a need for the system to assist in keeping this information accurate.

Personnel: Connected to personnel, there is a need for a CMMS that can register information like competences and cost information for both internal- and external personnel. Additionally, external staff should be able to use the system.

Scheduled maintenance: Most of the needs in the scheduled maintenance group emphasises on the ability to register, change and adjust preventive maintenance plans for each machine. The system also needs to be able to turn the PM-plans into work orders for a given timeframe.

Spare part handling: A standardised system needs to be able to handle spare parts on a basic level, storing information about all spare parts used, their suppliers, lead times, costs and inventory positions. Additionally, there is a need for some more advance functions, like calculating expected demand and re-order points, create purchasing orders and offer the possibility to view the spare part inventory of other Trelleborg sites.

Supplier characteristics: This group of needs were more tied to the supplier of the CMMS instead of actual functions of the system. There was a clear need of being able to easily get in contact with system support when needed. Furthermore, the need of having the CMMS available in the local language was also highlighted.

Usability: The usability group mainly consisted of needs connected to making the use of the system as simple as possible. Among those needs were general user-friendliness and a number of needs addressing the ability to customise the interface depending on the user needs.

Work order handling: The needs in this group are closely linked work order module of a CMMS. The system needs to provide a way to create and edit of work orders that can be used by anyone at the plant, including operators. It needs to be a simple way to notify the maintenance staff of an issue, and also provide a way for them to show that they have noted the issue.

7.2 Contribution to theory

Current research is clear on the potential benefit of having a well-functioning Computerised Maintenance Management System in a plant (Peters, 2006; Kans, 2008; Carneo, 2015). This suggests that an industrial group could benefit from choosing a single system and standardising it, thereby making sure that every plant in the group are working with a well-functioning system that supports the group's strategy. However, the initial literature review found no published research on the subject of standardising a CMMS in an industrial group. Through this thesis the current theory on CMMS has been extended into the context of an industrial group and covers the feasibility and benefits of a standardised system as well as important factors to consider when choosing a system.

The literature review also identified a gap in theory when it comes to the choice of CMMS. All research found on the topic was in the context of a single manufacturing plant considering to implement a system, which is of uncertain usefulness in the more complex situation where an industrial group is looking to find one system to apply throughout the whole group. To assist in this choice, a step-by-step procedure to identify an industrial group's needs of a standardised CMMS was developed. This approach extends the current theory on CMMS need identification in the context of an industrial group. The approach was inspired by Kans' (2008) approach to identify maintenance management IT-needs in a single plant, and through that it could be determined whether the industrial group context had other requirements than the single-plant.

An additional aspect that was missing in the current processes for identifying needs was the process of turning the gathered data into something structured that could be usable when evaluating a system. To assist with this, inspiration was taken from Ulrich and Eppingers (2012) need identification process in product development in order to ensure a strong, structured finish. This can be used to complement the current theory on CMMS need identification, either as a part of the process developed in this thesis, or to close the loop in an already published model like Kans' (2008).

7.3 Recommendation to the case company

The initial recommendation for Trelleborg is to raise the knowledge regarding TPM throughout the plants in order to facilitate a structured approach to maintenance at all of the plants of the group. During the interviews the plants were asked to describe TPM, and none of them mentioned all pillars. Neither did the plants work with all of the pillars stated in the philosophy. Since a CMMS is just a tool to enhance a structured approach, not a way to create one, all plants must establish a maintenance strategy before moving on to using a CMMS.

The empirical data also showed that several of the plants that were contacted, despite rating their maintenance system use 3 or higher on the Manufacturing Excellence self-assessment report either had old, partially obsolete systems, home-made solutions, or no maintenance system at all. Moreover, the majority of the plants contacted were in some extent unsatisfied with how their current system was working. A well-functioning maintenance system is key to realising the full benefits of working with TPM. Therefore, once the structured approach to maintenance is in place, Trelleborg is recommended to find a CMMS to standardise. This project indicated that the plants within the group had fairly similar CMMS needs, although they might vary in importance between them. Moreover, the functions needed to support the operations falls within the range of standard modules present in most CMM-systems. So in Trelleborg's case it will be more about the system-, supplier- and- technology factors that will determine the system choice. Therefore, it is recommended that Trelleborg uses the needs presented in this thesis to start evaluating potential CMMS suppliers.

Two key factors affecting the system choice discovered in this thesis was the languages the system was available in as well as the global availability and language of the system support. In a global industrial group like Trelleborg with production sites in over 40 countries, these factors become a major decider for which systems that can be considered for a standardisation. Therefore, before applying the need specification mentioned earlier, the language requirements must be determined.

As the needs identified are the result of the interaction with about one third of the total sites in the group, Trelleborg is also encouraged to evaluate whether they consider the results representative for the group as a whole. If they are not, the recommendation is to either continue to gather operational raw data from more of the group's sites, and use the developed approach on that extended amount of data in order to identify additional needs that the first application might have missed. The second option is to send out a new survey to more of the sites within Trelleborg and ask them to rate the relative importance of the already identified needs. By comparing those results to the previous ones, it can be determined whether the not prompted plants have similar perception as the asked did, or if further investigation is needed.

If Trelleborg would consider a group-wide standardisation overwhelming, they are encouraged to at least try to standardise on BA or BU level as they still can achieve some of the benefits that way. In general, they recommended to improve the usage of their current systems. As showed in this study, many of the sites are not utilising their maintenance systems potential fully, and by increasing the utilisation they could improve their work with preventive maintenance which would improve their machine reliability and production effectiveness.

7.4 Suggestion for further research

Throughout the initial literature review no research on CMMS in an industrial group context was found, so before developing the need identification process, justification for attempting a standardisation had to be developed. By analysing the way of working with maintenance today in Trelleborg and comparing it with the current research on the effect of using a CMMS, this thesis has pointed out the theoretical benefits of standardising a CMMS in an industrial group. In order to determine whether these benefits are achievable, and if there are other benefits that cannot be derived from current theory, a case study on a company that has successfully standardised their CMMS would be valuable contribution to current research. Depending on the results, that study could motivate use the need identification process developed in this thesis, as well as motivate more research on the subject.

Choosing which system to standardise is a complex task that comes with both risk and reward as a poor system choice will affect several plants, multiplying the negative effect of an inadequate selection process. The need identification process developed in this thesis attempted to address this issue in a structured and generalizable way, but it has only been tested on the company it was developed in collaboration with. Based on this, there is no guarantee for that the process is usable at other companies. Therefore, further research in how well the factors mentioned in this thesis apply to another industrial group would be an area of interest. Not only to validate the process, but also to determine if the factors affecting the system choice are the same regardless of the characteristics of the group which the process is applied on.

Maintenance is often considered as a tactical issue by most companies and purely a support function to the production. This study has linked maintenance with the overall strategy, and it indicates that companies would benefit from making maintenance into a strategic question as well. Lean production has been the number one priority at manufacturing companies for several decades and is implemented at almost every site today. It is no longer a tool to get ahead of competition, but rather a way to stay in the game. Lean production's mantra of reducing waste has a highly synergistic relationship with machine reliability, which is the main responsibility of the maintenance department. By directing more attention to creating a structured approach maintenance, it should be possible to achieve competitive advantages. Based on this research on the interaction between Lean production and maintenance, as well as the benefit of turning maintenance into a strategic aspect would be of interest to push the evolution of efficient operations further.

7.5 Limitations

One of the limiting factors for this thesis has been the shortage of time. With more time allocated to carry out the project would it been possible to apply the newly developed need identification process on another industrial group in order to evaluate both its relevancy and generalisability. With more time available would it also have been possible to conduct more plant visits, which would have given the possibility to gather more data to base the analysis on.

Another limiting factors was that the sites visited during the thesis were all located in the northern part of Europe, and five of the six plants belonged to the same business area. It is possible that a more representative view of the group would have been achieved if more plants from different business areas and countries were visited. However, it is not certain that direct communication with key stakeholders would have been possible, as the blue collar staff at many plants does not speak English. Additionally, the selection of which sites to include in the empirical study was based on a self-assessment of maintenance maturity which all sites had conducted in 2014. A report that is purely based on self-assessment will never be completely impartial, but in this case was it considered to be the best information to use.

Finally, the level low level of TPM-maturity among Trelleborg's sites can potentially limit the generalisability of the process on companies that are working with TPM on a very high level. The data analysis and conclusion in the thesis has been based on Trelleborg's way of working, and it is possible that a group in the forefront of TPM work in a different way. On the other hand, a "state-of-the-art" plant most likely already have a well-functioning CMMS and would probably not highlight the problems related to those systems in the same way as Trelleborg did.

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Appendix A – Maintenance systems self-assessment

In order to decide which sites within Trelleborg group that should participate in the empirical study was a self-assessment report regarding Maintenance systems used as a point of reference. Below is first the form (see table 24) that all sites within Trelleborg group had fulfil in order to state their maturity and after that are a list (see table 25) of sites that were identified as interesting.

Maintenance systems

When equipment is used without proper maintenance, the machine will eventually break down or a line stoppage will result. Preventive maintenance (PM) of machines and equipment is the cheapest and least time-consuming solution. Everyone should get involved and understand the practice of preventive maintenance.

Table A.1 Manufacturing excellence maturity self-assessment (unpublicised document, Trelleborg AB).

Level		☑
1	• Machines are used until they break down	☐
	• Maintenance is carried out solely by maintenance staff	☐
	• Manufacturing feel they are too busy to hand over equipment for maintenance	☐
2	• The employees understand the need for preventive maintenance (PM) and PM schedules have been created for selected equipment	☐
	• A label on each machine states the maintenance technician responsible. Each machine has a maintenance log	☐
	• Important machines are labelled “designated PM Equipment” with first priority at breakdowns	☐
	• Each item of dedicated PM equipment has a check sheet used by the operator for daily inspection and by the maintenance technician for periodic maintenance and service	☐
	• OEE (Overall Equipment Efficiency) is measured and actively monitored	☐
3	• The employees have “adopted” the machines and know they are responsible for taking care of the machines they use, including cleaning the machine	☐
	• Often used and inexpensive spare parts and maintenance tools are kept nearby in labelled places	☐
	• Inspections, cleaning and maintenance follows a PM schedule	☐
	• More than 50% of maintenance activities are preventive, following the PM schedule	☐
	• OEE is improving for all measured equipment	☐
4	• Measurements are taken to check the “health” of the machines and to prevent breakdowns	☐
	• Systematic registration of breakdown data is used for improving OEE and design of new equipment	☐
	• Reorder points for consumables, spare parts and maintenance tools are based on risk analyses	☐
	• Sudden breakdowns are very rare	☐
	• The overall equipment operating rate (or OEE) is 75% or more	☐
5	• Focused improvements have made some machines better than new	☐
	• Machines produce only non-defective goods in the first run after each changeover	☐
	• Condition-based maintenance has been introduced	☐
	• The overall equipment operating rate (or OEE) is 85% or more	☐

Target group

Sites that were found to be interesting for the project. The list (see table 25) is the result of the self-assessment report regarding maintenance system which become the target group for the project. The sites have been anonymised and been replaced with numbers from 1 to 41.

Table A.2 Interesting sites for the project (unpublished document, Trelleborg AB)

Plant	Business Area	Current	Target	Prior Year
1	Industrial Solutions	N/A	N/A	N/A
2	Wheel Systems	N/A	N/A	N/A
3	Offshore and Construction	N/A	N/A	N/A
4	Industrial Solutions	N/A	N/A	N/A
5	Coated Systems	N/A	N/A	N/A
6	Industrial Solutions	4	4	4
7	Industrial Solutions	4	4	4
8	Sealing Solutions	4	4	4
9	Sealing Solutions	4	4,5	4,5
10	Sealing Solutions	4	4	3
11	Offshore and Construction	4	4	4
12	Industrial Solutions	4	4	4
13	Industrial Solutions	4	N/A	3
14	Industrial Solutions	4	4	3
15	Sealing Solutions	3,5	3,5	3,5
16	Sealing Solutions	3,4	3,8	2,8
17	Offshore and Construction	3,2	3,4	3,2
18	Industrial Solutions	3,1	4	2,5
19	Wheel Systems	3	4	4
20	Wheel Systems	3	3	3
21	Industrial Solutions	3	4	2
22	Industrial Solutions	3	4	3
23	Industrial Solutions	3	4	3
24	Industrial Solutions	3	4	3
25	Industrial Solutions	3	4	2
26	Industrial Solutions	3	3	3
27	Industrial Solutions	3	4	3
28	Industrial Solutions	3	3	3
29	Sealing Solutions	3	4	3
30	Sealing Solutions	3	3,5	3
31	Coated Systems	3	3	3
32	Sealing Solutions	3	4	3
33	Sealing Solutions	3	N/A	2
34	Sealing Solutions	3	3	1
35	Offshore and Construction	3	3	2
36	Industrial Solutions	3	3	3
37	Industrial Solutions	3	4	3
38	Industrial Solutions	3	3	3
39	Offshore and Construction	3	4	3
40	Coated Systems	3	3	3
41	Coated Systems	3	3	3

Appendix B – Interview Guide

Below is the interview guide that was used during the empirical study presented. It consist of questions for the Managers, Maintenance employees and Operators.

Interview questions: Managers

Introduction

1. What is your position and responsibilities?
2. How many employees do you have working with maintenance?
3. How many operators are working at the plant?
4. How many machines do you have at the plant that needs maintenance?

TPM – General

5. How would you describe TPM?
6. How do you work with TPM today?
7. How is the work organised?
8. How is the TPM-related information made available?

TPM – Effects of implementation

9. How has the implementation of TPM affected the way you work with maintenance?
10. What have been the benefits of this change?
11. Have you experienced any drawbacks?

Continuous improvement

12. How do you identify problems to work with?
13. How do you work with the problem in order to solve it?
14. How and how often are the improvements followed up?

Business Area collaboration

15. Are you collaborating with any other plants within your business area? If so, what kind of collaboration do you have?
16. Is there any possibility to share inventory between sites?
17. Do you have any ongoing information sharing?
18. What is the general view of cooperation between sites?

General questions regarding IT-skills

19. How would you describe the general IT-knowledge in the plant?
20. What other IT-systems do you have implemented in the production?
21. What is your experience from working with those systems?

Autonomous maintenance

22. What kind of maintenance work is carried out by the operator?
23. Are there written instructions regarding autonomous maintenance for specifics machines?
    - When and how are those instructions made?
24. Do you have any way of tracking how much time is spent on autonomous maintenance?
25. In which way is the CMMS system used to work with autonomous maintenance? For example: Information about the machine, maintenance instructions, cleaning instructions.
26. Is a basic condition for the machine stated and could it be found in the CMMS?

Reactive maintenance

27. Do the operators take action in the reactive maintenance?
    - If yes, in that case, in what extent?
28. If maintenance staff is needed to fix a breakdown, how are they contacted?
29. Is the work order logged in the system, and in that case how?
30. Is the work order recorded in the same way and to the same extent, regardless of who is carrying out the reactive maintenance?
31. Are the any machines that are prioritised for reactive maintenance?
32. How do the maintenance staff know which machines that are prioritised?
33. Is there something about the logging that you think could be done in a smoother way?
34. Are the breakdowns automatically recorded in the system?

How do you work with preventive maintenance?

35. How do you work with preventive maintenance?
36. How far in advance is the maintenance planned?
37. How do you identify which machines to target, and which actions to take?
38. How do you use the CMMS system when working with preventive maintenance?

Follow-up on maintenance

39. What kind of follow-ups do you do on your maintenance performance?
40. What perimeters are evaluated?
41. How often is the follow-up carried out?
42. Is the information needed easy to access?
43. Do you have way of knowing how much each machine costs in maintenance?
44. Are there any perimeters that you don't have right now, but would like to evaluate?

Personnel and Internal/External Resources

45. Do you have any system for keeping track of your internal-/external resources, their competencies and how much they cost?
46. When planning maintenance, how do you keep track of which resources are allocated where?
47. If so, what are the best/worst things with the current system?
48. How are the maintenance labour costs followed up?

Information handling

49. How do you handle machine-related information, like its technical data, instruction books or maintenance history?
50. What information is stored for each machine?
51. What is the stored data used for?
52. Do you feel that you are missing any data regarding the machines?
53. Who is responsible for keeping this information accurate?
54. How is this information presented?
55. How often is this information reviewed?

Data gathering

56. In which instances is new information entered into the system?
57. What is entered, and who is responsible for doing it?
58. How is it entered (portable device, computer at office etc.)?
59. What kind of data is automatically gathered from the equipment?
60. Do you experience any problems with the current way of entering information?

Spare parts handling

61. How do you keep track of the spare part inventory?
62. Are the stock levels updated in real-time?
63. Does the system provide expected demand on spare parts?
64. Does the system provide suggested reorder points?
65. Does the system display spare part cost?
66. Is the system connected to the purchasing platform?
67. Does it record history of spare parts used for the equipment?

General CMMS questions

68. Why did you choose the current system?
69. How did the process for choosing the current CMMS system?
70. How many users do you have in your system?
71. Do you have any experience with other systems?

Functionality

72. What do you think works well with the system you are using?
73. Which of the available functions in the CMMS-system are you using?
74. Are there any functions that you do not use?
75. Are there any features you wish you had in the CMMS-system?
76. Are there any functions that are unsatisfying?

Interview questions: Maintenance employees

Introduction

1. What is your position and responsibilities?

TPM – General

2. How would you describe TPM?
3. How do you work with TPM today? (how does TPM affect your daily work?)

TPM – Effects of implementation

4. How has the implementation of TPM affected the way you work with maintenance?
5. What have been the benefits of this change?
6. Have you experienced any drawbacks?

Continuous improvement

7. How do you identify problems to work with?
8. How do you work with the problem in order to solve it?
9. How and how often are the improvements followed up?

General questions regarding IT-skills

10. Do you have any other IT-systems that you use on a daily basis?
11. What is your experience from working with those systems?

Autonomous maintenance

12. What kind of maintenance work is carried out by the operator?
13. Are there written instructions regarding autonomous maintenance for specifics machines?
14. When and how are those instructions made?
15. Is a basic condition for the machine stated and could it be found in the CMMS?

Reactive maintenance

16. Do the operators take action in the reactive maintenance?
    - If yes, in that case, in what extent?
17. If you are needed to fix a breakdown, how are you made aware of that?
18. Is a work order logged in the system, and in that case how?
    - Is the work order recorded in the same way and to the same extent, regardless of who is carrying out the reactive maintenance?
19. Are the any machines that are prioritised for reactive maintenance?
    - How do you know which machines that are prioritised?
20. Is there something about the logging that you think could be done in a smoother way?
21. Are the breakdowns automatically recorded in the system?

How do you work with preventive maintenance?

22. How do you work with preventive maintenance?
23. How far in advance is the maintenance planned?
24. What information do you base the planning on?
25. How do you use the CMMS system when working with preventive maintenance?

Follow-up on maintenance

26. What kind of follow-ups do you do on your maintenance performance?
27. What perimeters are evaluated?
28. How often is the follow-up carried out?
29. Is the information needed easy to access?
30. Are there any perimeters that you don't have right now, but you think should be?

Personnel and Internal/External Resources

31. When planning maintenance, how do you keep track of which resources are allocated where?
    - If so, what are the best/worst things with the current system?

Information handling

32. A part of facilitating as effective maintenance as possible is to keep information about every machine easily accessible for maintenance staff and managers – How do you handle machine-related information, like its technical data, instruction books or maintenance history?
33. What information is stored for each machine?
34. Do you feel that you are missing any data regarding the machines?
35. Who is responsible for keeping this information accurate?
36. How is this information presented?
37. How often is this information reviewed?
38. What is the stored data used for?

Data gathering

39. When do you enter data into the system?
40. How is it entered (portable device, computer at office etc.)?
41. What kind of data is automatically gathered from the equipment?
42. Do you experience any problems with the current way of entering information?

Spare parts handling

43. How do you keep track of the spare part inventory?
44. Are the stock levels updated in real-time?

45. Does the system display spare part cost?
46. Does it record history of spare parts used for the equipment?

General CMMS questions

47. Do you have any experience with other systems?

Functionality

48. What do you think works well with the system you are using?
49. Which of the available functions in the CMMS-system are you using?
50. Are there any functions that you do not use?
51. Are there any features you wish you had in the CMMS-system?
52. Some functions that are unsatisfying?

Interview questions: Operators

Introduction

1. What is your position and responsibilities?

TPM – General

2. How would you describe TPM?
3. How do you work with TPM today?

TPM – Effects of implementation

4. How has the implementation of TPM affected the way you work with maintenance?
5. What have been the benefits of this change?
6. Have you experienced any drawbacks?

Continuous improvement

7. How do you work with the problem in order to solve it?

General questions regarding IT-skills

8. What other IT-systems do you use on a daily basis?
9. What is your experience from working with those systems?

Autonomous maintenance

10. What kind of maintenance work do you carry out?
11. Are there written instructions regarding autonomous maintenance for specifics machines?
12. In which way is the CMMS system used to work with autonomous maintenance? For example: Information about the machine, maintenance instructions, cleaning instructions.
13. Is a basic condition for the machine stated and could it be found in the CMMS?

Reactive maintenance

14. Do you take action in the reactive maintenance?
    - If yes, in that case, in what extent?
15. If maintenance staff is needed to fix a breakdown, how are they contacted?
16. Is the work order logged in the system, and in that case how?
    - Is the work order recorded in the same way and to the same extent, regardless of who is carrying out the reactive maintenance?
17. Is there something about the logging that you think could be done in a smoother way?

How do you work with preventive maintenance?

18. How do you work with preventive maintenance?

19. How do you use the CMMS system when working with preventive maintenance?

Information handling

20. Do you feel that you are missing any data regarding the machines?

Data gathering

21. Do you enter any data into the CMMS system?
22. How is it entered (portable device, computer at office etc.)?
23. Do you experience any problems with the current way of entering information?

Functionality

24. What do you think works well with the system you are using?
25. Which of the available functions in the CMMS-system are you using?
26. Are there any functions that you do not use?
27. Are there any features you wish you had in the CMMS-system?
28. Some functions that are unsatisfying?

Appendix C – Maintenance processes within Trelleborg

Below are a flow charts over the maintenance procedures at the sites how were visited during the empirical study. The sites have been anonymises listed from A-F. The flow charts were constructed according to how the authors perceived the maintenance procedures.

Plant A

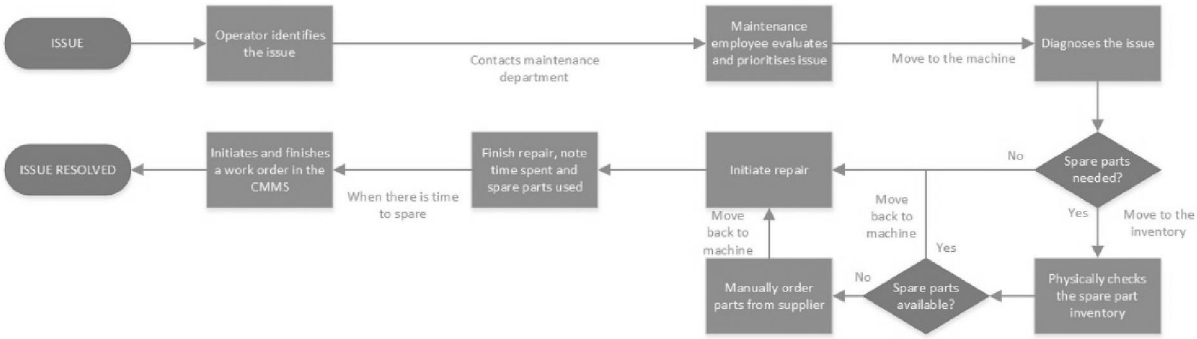

Figure C.1 Flow chart over plant A maintenance procedures.

Plant B

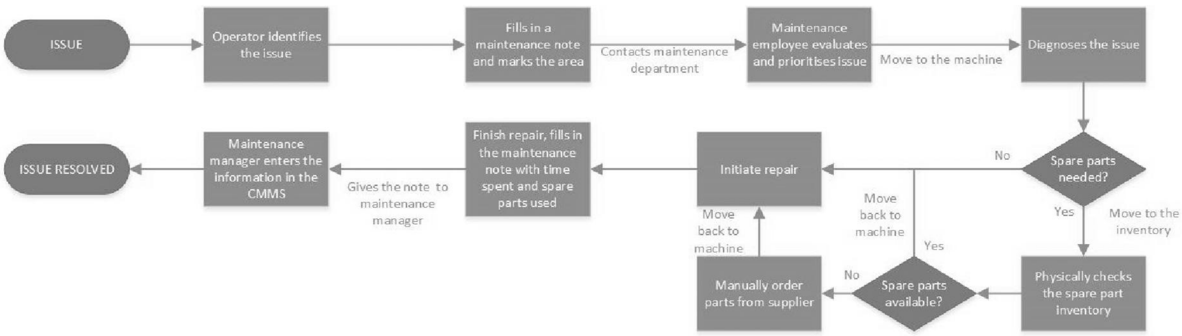

Figure C.2 Flow chart over plant B maintenance procedures.

Plant C

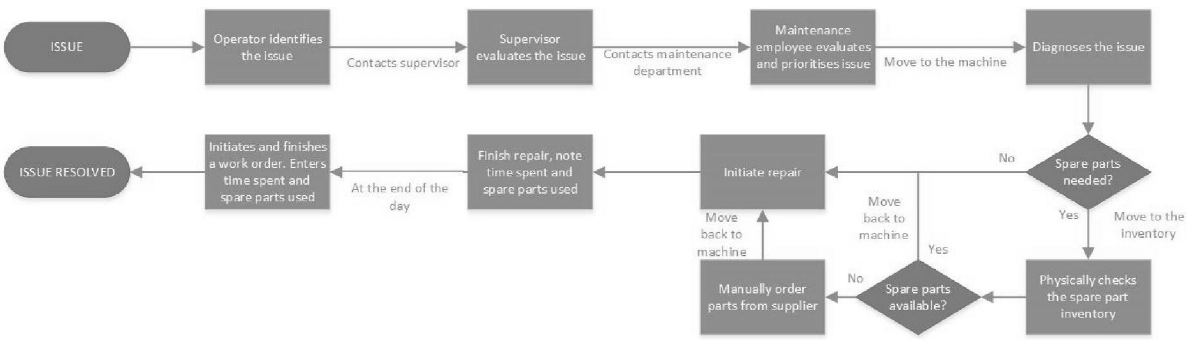

Figure C.3 Flow chart over plant C maintenance procedures.

Plant D

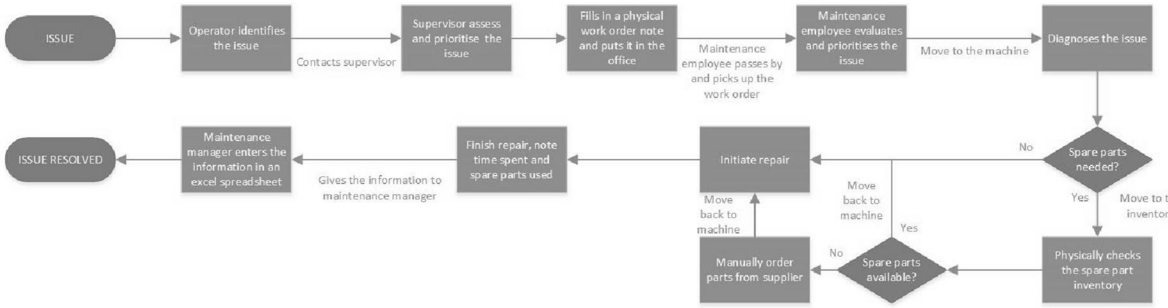

Figure C.4 Flow chart over plant D maintenance procedures.

Plant E

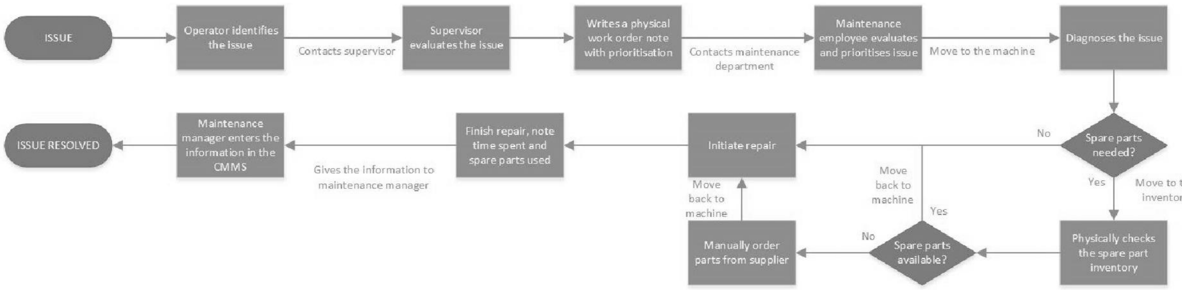

Figure C.5 Flow chart over plant E maintenance procedures.

Plant F

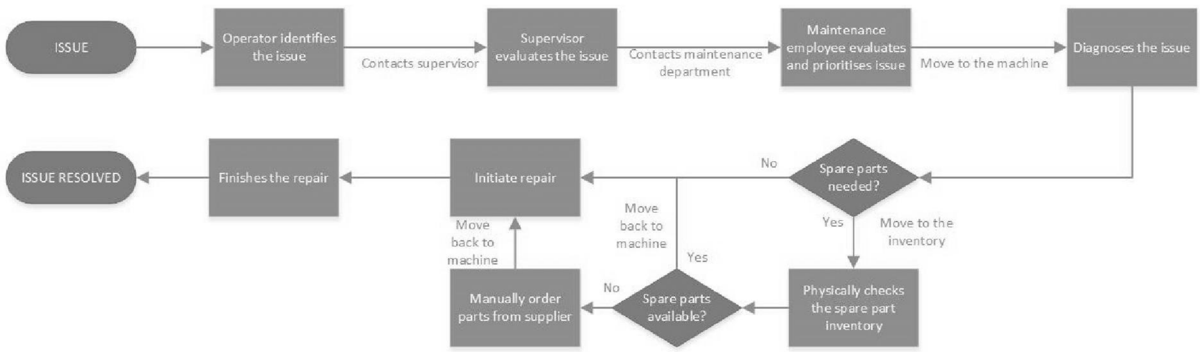

Figure C.6 Flow chart over plant F maintenance procedures.

Appendix D – Interview answers

Below are the answers which were received during the site visits presented in same categories as in the interview guide. To the left is the questions presented in the interview guide and the answers from the plants are in the coloured columns.

Table D.1. Characteristics facts for visited plants (interview, Trelleborg Group).

		Plant A	Plant B	Plant C	Plant D	Plant E	Plant F
	Process type	Batch	Line and batch	Batch	Batch and jobbing	Batch	Batch
	Critical machinery	Yes	Yes	Few	No	Few	Few
	Present maintenance syster	Modern CMMS	Excel & home-made Lotus Notes based "CMMS"	Obsolete CMMS	Excel based system	Obsolete CMMS	Excel based issue report & obsolete CMMS
	Maintenance system use	PM planning, Spare part handling, Machine related information	PM planning, Some spart part handling	PM planning	PM planning	PM planning	PM planning, Continious improvement
1	Interviewees	Production Manager & Maintenance Manager	Plant Manager, Production Managers, Building Manager	Process Technical Manager	Manufacturing Excellence Manager, Maintenance Manager	Manufacturing Excellence Manager, Engineering Manager, Production Manager	Operations Manager, Maintenance Manager
2	Employees in maintenance	13	1 + 3 external	4 + some external	2 + 2 external	3 external	3
3	Operators	95	123	250	MAIL	MAIL	90
4	Machines needing maintenance	about 100	-	700-800	MAIL	80 presses and a lot of other machines	Around 100

Table D.2 TPM-general (interview, Trelleborg Group).

	TPM-general						
5	Describe TPM	Operators conduct maintenance		Preventive maintenance	Give operators daily maintenance tasks		Operators helping out with daily maintenance
6	How do you work with TPM today?	Autonomous maintenance, PM	Some autonomous maintenance, PM	They don't. Have own PM philosophy	5S, PM, autonomous maintenance on test		PM

Table D.3 TPM – effects of implementation (interview, Trelleborg Group).

TPM - effects of implementation							
8	How is the TPM-related info made available?	Through TPM-boards at every machine showing the important factors for each machine. KPIs, followups, improvement suggestions etc	Information boards and instructions on the different machines	Some basic information on boards out in the production, and instructions in lotus notes	5S canvas in the production, KPIs. Autonomous maintenance instructions on each machine	Boards at the entrance to the production	-
9	TPM implementation - affected maintenance work			No effect, already worked with PM philosophies before TPM	Positive effects of the parts implemented. Some basic activities put on the operators	Big positive effect, staff takes pride in having a clean and tidy plant. Better production structure	-
10	TPM benefits	have become very involved in the autonomous maintenance. However, there has been no shown improvements in the ERP system, and improvements has partly been ignored	Maintenance staff get more time to work on more advanced tasks	-	gives the maintenance staff more time to focus on relevant tasks/PM. Cleaner production area. Better organisation about maintenance in general		-
11	TPM drawbacks	Not everybody embracing	Not everbody embracing	-	Not everybody embracing	Not really	-

Table D.4 Continuous improvements (interview, Trelleborg Group).

Continious Improvement							
12	How do you identify problems to work with	Paper based. Issue --> note on improvement board. Task then assigned to responsible	Paper-based. Issue--> mark machine part --> note to maintenance dept. Improvement suggestions collected	Verbal/written input from operators and maintenance staff, sometimes bigger project from management	5S seminars at machine level, operators brings ideas to supervisors, ME manager gets inspiration from other plants	Management identifies issues. Operators do not come with suggestions. Finance department driven - identify areas to improve in based on figures	An excel-based database where supervisors enter issues. For ME projects, the operations team come with ideas. Daily meetings with the operators were
13	How do you work with the problem in order to solve it?	PDCA, QC-story. Daily meetings	Through improvement suggestion, once a year	In cross-functional teams of employees, getting a task to solve	Operator tells supervisor, supervisor forwards it to maint. Mgr, who puts it in the PM plan	Management assigns improvement activities to different departments or persons	Start a project around it
14	How often are improvements followed up?	Monthly followup. Excel sheets with goals, and then being followed up	They are not	They are not	Never followed up. Cause of the way the system works	Never	Goals are set for the project, check against those.

Table D.5 BA collaboration (interview, Trelleborg Group).

BA collaboration							
15	Any collaboration with other plants in BA? If so, which kind?	Bencmarking. Collaboration in maintenance with other Trelleborg plant. Contacts created via the ME school	Benchmarking against the US and the Shanghai plant	Cost benchmarking, info sharing with other managers based on personal network	Information sharing with a two other, similar Trelleborg plants. Only one way information from plant D.	ME manager is in charge of all the BU plants in the area, so contact via that	Through Trelleborg Blue
16	Is there possibility to share inventory?	If same type of machines	They doubt that	Not interested. Would be a good thing to see what the other plants had in inventory, if in urgent need	Yes. But needs a new CMMS system they can have better info	No	That is unclear
17	Do you have any ongoing information sharing	No	The benchmarking mentioned earlier	Nothing on long term regarding maintenance.	Not at the moment	No	No
18	What is the general view on cooperation?	Positive, would like more	Generally a positive attitude towards co-opertions, although it can be limited resulsts coming from a co-peration	It is positive, increasing the sharing a bit would be beneficial	More than positive to more collaboration in different forms with other plants within Trelleborg	Positive! More dialogue between managers	Positive, however corporate/BA initative would be needed

Table D.6 IT-skills (interview, Trelleborg Group).

IT-skills							
19	Describe the general IT-knowledge in the plant	Decent general IT-knowledge, they can carry out the daily tasks in the CMMS without a problem.	Pretty decent. Operators know how to handle the monitoring systems	Good general knowledge. Both maintenance staff and operators able to easily handle regular software systems in the factory.	All personnel can handle the current systems, and enough knowledge to handle the new system aswell	Good enough to handle a simple CMMS for sure. Given it is fairly user-friendly	Good. They use both tablets and scanners
20	What other IT systems do you have?	Axxos (ERP) and filemaker (program linked to a customer), CMMS, Rejos	Exsitec - building 3, Rubin - Leif, own program - Lotus, M3 ERP	ERP system, barcode scanning for loading CNC programs and coding breakdowns	none	Fourth Shift (ERP system)	Barcode scanning and ERP system
21	What is your experience working with those?	Working well	Its doing that it is supposed to be	It works well, although the ERP is really old, and the CMMS is not optimal	N/A	It has been working well, and everybody involved likes it	They work fine once people get used to them

Table D.7 Autonomous maintenance (interview, Trelleborg Group).

Autonomous maintenance							
22	What kind of maintenance work is carried out by the operator?	Look, identify, check oil, feel.	Daily maintenance like lubrication, tightening bolts and other simple tasks (checklist)	Only cleaning and 5S. Don't want to involve the operators	5S activities, cleaning, lubrication, oil filter change, visual inspection, oil filling	Nothing, only observations according to a daily checklist	Very little, only go through inspection checklists. Had a plan but it is not working.
23	Are there written aut. Maint. Instructions?	Yes, on each machine	There are manuals on each machines of how to do it	For cleaning and 5S there is instructions in lotus notes	Yes, in the selected area. To-do-list with pictures on each machine.	Only daily checklist	-
24	- how are those instructions made?	By the maintenance department	By the maintenance department	-	Done in collaboration with ME manager and maintenance staff	By maintenance & production manager	-
25	Any way of tracking time spent on autonomous maint?	Not while running, but an approximation while machine is stopped.	No, the maintenance staff just approximate time spent	-	Timed it when starting with aut. Maint.	No	-
26	In which way is the CMMS used in the work with aut. Maint?	Not used	Not at all	It holds basic info about the machine and maintenance history.	Not using	Not using a CMMS for that	-
27	Is the basic condition of the machine stated?	Yes, Takt and time, ERP checks it	The instruction books usually cointain that, and they are available	No	No	No	No

Table D.8 Reactive maintenance (interview, Trelleborg Group).

Reactive maintenannce								
28	Do the operators take part in the reactive maintenanace?	No, they call maintenance, but can stay and help out	Only easy-to-fix faults experienced earlier in a part of the plant,	Not at all	Yes, but only very simple things	Only the very simplest things, like tightening a bolt	No
30	How is maintenance staff contacted?	By phone	In building 1,2 by phone, in buiding 3 by finding the production manager	By e-mail or phone, operator -- >supervisor--> maintenance	If urgent; by phone. Operator --> supervisor --> Wo --> maint. Staff	Operator contacts the supervisor, who writes a work order. By phone if urgent	By phone
31	Is the WO loggen in the system, and how?	Yes, done at a stationary computer	Yes, B1&2- managers office, B3- workshop	Yes, maintenance staff registers at their office- computer. With time estimation, and the end of the day	By hand, in an excel spreadsheet. Start out with a Job-card being filled in, contains time for maintenance, parts used and comments on the card	Yes, engineering manager logs them in the system afterwards. Collects the green tickets and enter them	Not logged
32	Is the WO recorded in the same way/extent, regardless of who is carrying out the reactive maint?	Maintenance staff both create and close the work order. Reasonably good reports	Yes	Yes, because it is only the maintenance staff who does it	Generally, yes. If really urgent, might miss to fill WO	Yes, except for small things done by operators.	-
33	Are there any machines that are prioritised for reactive maint?	The machines employed with 3 shifts	No	Yes, some critical machinery. High- medium-low prio	Yes, from a scale from 1-3 depending on how crucial they are	Yes, all machines with the risk of stopping the production has high prio, medium for the other machines, low other	No, only if there is an urgent order needing to be done at that machine
34	How do the mainteance staff know which machines are prioritised?	Yes	-	It is written down, if there is any doubt they ask maintenance manager	Stated by management, and communicated to maintenance staff. Production will tell if there are any critical breakdowns	It is stated by engineering manager	Thorugh the supervisors who has overview of the orders
35	Is there something about the logging that could be done smoother?	It is okay, you get the data that is required	Yes, to do it in excel or word is not efficient, takes much time to enter, and lacks much information	It is not a user- friendly system, could give operators access, slow system	Time tracing, digital system, the operators could report straight into the system	Everything	Not logging at the moment
36	Are breakdowns automatically recorded in the system?	It is recorded in the ERP, not into the CMMS though	No	Not at the moment, however another system records it	no	No	No

Table D.9 Preventive maintenance (interview, Trelleborg Group).

	Preventive maintenance						
37	How do you work with preventive maintenance?	All machines are present in the CMMS, where the intervals are planned based on experience	Weekly job lists from the lotus-notes based system	Identify non-standard behaviour and then consider how to fix it. Recurring PM on equipment specific intervals. Intervals updated and changed based on experience	According to a weekly PM plan done by the maint. Manager. Based on some experience, but mainly instruction books	PM work orders are generated on a weekly based, work trough them while taking care of the reactive issues	That is what the CMMS is used for today. Prints a list of PM tasks each week, staff works their way through it
38	How far in advance is the maintenance planned?	Stored in the CMMS, and is handed out on a weekly basis	a week	Recurring work orders on a weekly basis. Situation dependent for other things	week-to-week basis	a week	A year, but printed on a weekly basis
39	How do you identify which machines to target, and which actions to do?	experience and the machines instruction	Instruction books	Input from operators, and performance measures. Actions come from instruction books and experience	Instruction books	PM is taken from the instruction books	Based on the instruction books and safety regulations
40	How do you use the CMMS when working with PM?	Generate weekly PM work orders	we dont	Stores recurring and single created PM, generate list on a weekly basis. If it is carried out, it will still be in the list. Statistics history from the system is used to tweak the intervals	Don't have a CMMS	It gives suggestions of what to do each week. But the instructions are out of date, and database contains machines not even present anymore	It holds all the service intervals and gives suggested jobs each week

Table D.10 Follow-ups on maintenance (interview, Trelleborg Group).

	Follow-up on maintenance						
41	What kind of follow-ups do you do on your maintenance performance?	Daily meetings, and maintenance meeting every 14 days	None	No mre than regular checkup on machine performance	None	Basically none. Only thing is that the manager does a visual follow-up after a big breakdown	Not much
42	What perimeters are evaluated	Unplanned machine-stops	Specific perimiters developed on site	no particular	OEE has been followed up a bit, but was very time consuming. Garbage in, garbage out.	None	N/A
43	How often is the follow-up carried out?	weekly	building 1&2-weekly, 3-daily	No special maintenance followup	Irregular	Never	N/A
44	Is the information needed easy to access?	Yes, provided by the ERP system	No. For the people working with the systems every day it is doable. But should be much easier to generate reports	N/A	N/A	No, it is not easy to generate in the system. Very bad report function	N/A
45	Do you have any way of tracking each machines maintenance costs?	By asking the controller to summarise the costs	no	The information is there, however not put together in a structured way. Requires some detective-work. Spare part costs are not in the system	No, no good way	Only really big projects on specific machines	no
46	Are there anything you dont have right no, but would like to evaluate?	Happy with the reports from the ERP system	Costs per machine	Absence of an analysis tool is the main problem. Also want more automatic gathering	MAIL	Downtime, cost knowledge, spare parts used	-

Table D.11 Personal and internal/external resources (interview, Trelleborg Group).

Personnel and internal/external resources							
47	Do you have any system for keeping track of internal/external resources, their competencies and their costs?	Maintenance mgr knows them, not in the system however	The manager knows what the external contractors cost	No	no	No, only connection to price is the invoices	Excel for the operators, not for the maintenance staff however. No way of tracking costs, only by checking invoices. Would be very good to have
48	When planning maint, how do you keep track of which resources are allocated where?	They don't	They dont	Since its only 4 maintenance people, not much tracking needed. Required skills for some things are stated in lotus notes	They dont	They dont	They don't
49	If so, what are the best/worst things with the current system?	-		Best: Easy to edit and create WO, hierarchy layout. Worst: No analysis tool, therefor not a structured input of data either	no	-	-
50	How are the maintenance labour costs followed up?	Should be put into the program	At the budget meetings	They are not	-	-	If an invoice is unusually high, economy will react and contact operations manager. But that's about it

Table D.12 Information handling (interview, Trelleborg Group).

Information handling							
51	How do you handle machine-related info?	Mostly in the CMMS	In paper	Basic machine related info is in the CMMS on "cards". Instruction books are in a physical library. Maintenance history is stored on the CMMS	In physical copies outside maint. Managers room	Majority in the CMMS, or on the intranet. 40% physical	Most in PDF format, but some in printed form aswell
52	What information is stored for each machine?	Instruction books, certifications etc	Maintenance history	Machine id, position at site, name of supplier, purchase date, references to instructions, info regarding recurring maintenance, maintenance history, guarantees etc.	name, number, supplier, purchase date, warranties, service papers	Instruction books, adaptations done to the machine, and some safety regulations and risk assessments. But not maintenance history	Instruction books, safety information
53	What is the stored data used for?	For reference	Reference	history - evaluate the PM intervals. Track guarantees, for reference	Reference when repairing, warranty and very specific follow ups	For reference when doing maintenance	For reference when repairing
54	Do you feel that you are missing any data regarding the machines?	no		Yes, more info in order to be able to track OEE etc.	Yes, very much, and the data available is bad. Breakdown data, and other OEE related parameters	-	Maintenance history
55	Who is responsible for keeping this info accurate?	Maintenance manager	Unclear	Process Technical Manager	Maintenance manager	Engineering manager	Unclear
56	How is this information presented?	mainly in PDF format	In the system you can filter by machine	On cards in the system	In binders	-	in directories, or in physical form
57	How often is this info reviewed?	Every new aquisition	When a new machine is bought	Continious process, do little by little. There is also an internal audit to check it	Never followed up	When a machine is moved, or when legislations change	never

Table D.13 Data gathering (interview, Trelleborg Group).

Data gathering							
58	In which instances is new information entered into the system?	After an inspection, or an aquisition	B1&2 when a work order is completed, B3 when a tool is serviced	When aquiring a new machine. WO reporting at the end of the day	On the T-cards when a job is finished. Or when a new machine is bought	When engineering manager reports in a WO. Or a new machine is bought	When a new machine is bought
59	What is entered, and who is responsible for doing it?	Maintenance manager or maintenance manager (Depends)	Production managers and maintenance personnel for tools	Which machine, what is done, spare parts used, time spent and who did it	Which machine, what is wrong, why, time of breakdown, description	Job description, time spent, parts used. Maintenance manager	Maintenance intervals from instruction book, maintenance manager
60	How is it entered(portable device, computer etc?)	Computers. Potentially good with portable devices	Computers at offices	At a computer in the maintenance room at the end of the day	manually in excel, in maintenance managers office	Computer at engineering managers office	Computer
61	What kind of data is automatically gathered from the equipment	Stoptime, error codes	None	Nothing in the system. But CNC machines have tracking of downtime and quality	none	None	None
62	Do you experience any problems with the current way of entering information	Double-handling in the information gathering. Maintenance staff might only finish jobs once a week	It is rather time-consuming in parts of the plant	time spent on maintenance is only estimated, smaller jobs not always recorded	It is very time consuming, and not accurate	It is very time-consuming for the engineering manager, who has to do it all manually	No problem for the information entered at the moment

Table D.14 Spare parts handling (interview, Trelleborg Group).

Spare parts handling							
63	How do you keep track of the spare part inventory?	They are in the CMMS	It is in the lotus-notes system	Only have inventory for critical spare parts. Not in the system	no	They dont. Maintenance staff orders what is needed. Much inventory over long time. Trying to identify strategic component at the moment	They Don't. Have some parts in stock, like oils. Otherwise all parts with a lead time of up to 2 days is ordered when needed
64	Are the stock levels updated in real-time?	no	No, just when the job is finished	no	N/A	N/A	N/A
65	Does the system provide expected demand on spare parts?	no	no	no	N/A	N/A	N/A
66	Does the system provide suggested reorder points?	no	no	no	N/A	N/A	N/A
67	Does the system display spare part costs?	no	no	no, in best case it displays the last purchase of that item. But that could be 10 years ago	N/A	N/A	N/A
68	Is the system connected to the purchasing platform?	no	no	no	N/A	N/A	N/A
69	Does it record history of spare parts used for the equipment?	Yes, if registred with the WO	Yes, if it is entered in the WO's	Yes, the maintenance staff enters spare parts used, but only has informational text	N/A	N/A	N/A

Table D.15 General CMMS questions (interview, Trelleborg Group).

General CMMS questions							
70	Why did you choose the current system?	It was easy to work with!	Created it after their needs	Unknown, the system is quite old	It is simple	Prior manager choose it for whatever reason	Unclear, former maintenance manager choosed it, most likely because it came from the same supplier as the old
71	How did the process for choosing the current CMMS system look?	Maintenance manager., the electrical supervisor and mechanical supervisor decided it together	Organic growth	Unknown	Maint. Manager chosed the system on his own	unknown	Just took it, former maint. Manager usually took the easy paths
72	How many users do you have in your system?	13 internal + 2	2 + 3 external	Around 7, manager+ 4 maintenance staff + 2 external	1, maintenance manager	2	1, maintenance manager
73	Do you have any experience with other systems?	IFS CMS, it was working decent, but the work orders were tedious	no	no	no	Some from a previous system, worked better than the present	no

Table D.16 Functionality (interview, Trelleborg Group).

Functionality								
74	What do you think works well with the system you are using?	Everything		Easy and intuitive to use and edit planned WO's. Easy to navigate thanks to hierarchy structured system	It is visual and simple	The reporting of finished work orders is okay	The PM-module works okay, however jobs printed disappear after that week if they are not finished
75	Which of all the available functions in the CMMS are you using?	PM, Time-reporting, invoicing, spare parts handling	N/A	Planning maintenance, information about machines and some spare parts & equipment history.	N/A	PM planning	PM only
76	Are there any functions that you do not use?	There are a few	N/A	Yes, especially file-handling	N/A	pretty much all the others	All the others
77	Are there any features you wish you had in the CMMS?	-		A good analysis tool getting data from other systems aswell	Everything, but especially follow ups and less time-consuming input	Inventory management, and that data is easy to input	A good way to handle spare parts
78	Are there any functions that are unsatisfying?	-		Most of them	N/A	The system is generally unsatisfying	-

Appendix E – Survey

In this appendix is about the survey which was developed and used during the thesis.
The survey consist of four parts, each part is developed to learn more about specific questions.

Introduction

This survey is being sent out as a part of a Master Thesis being performed within Manufacturing Excellence at Trelleborg. This thesis acts as the final examination for mechanical engineering students at Lund University, Sweden. The subject of the thesis is to evaluate Computerised Maintenance Management Systems (CMMS) and how they can support an effective preventive maintenance, especially with regards to TPM. The aim is to define a best practice solution for Trelleborg and to evaluate which CMMS solutions that could be most interesting for Trelleborg going forward.

The purpose of this survey is to gain an understanding of how the different production sites in the Trelleborg Group works with maintenance today, and how effective maintenance can be supported by IT-systems.

The respondent for this survey should be the person <u>responsible for the maintenance</u> at the plant.

The survey will take approximately 15-20 minutes.

Part 1 – General questions

1. Name?
2. Position?
3. Name on plant and business area? (drop down meny för valet av BA)
4. How many blue collar staff are working at the plant?
5. How many are working at the maintenance department? (If using external contractors, how many are performing maintenance at the plant every week?)
6. How many machines do you have that needs maintenance? Drop-down meny, 0-50, 51-100, 100-150…..950-1000, 1001 or more.
7. How much time is spent on planned vs. reactive maintenance (in %)?
8. Do you currently have a Computerised Maintenance Management System (CMMS)*? [Explanation: A Computerised Maintenance Management System (CMMS) is a software that maintains a database of information about an organisation's maintenance operations. The information stored is intended to help maintenance staff to work more efficiently and to help management to make informed decisions.]
    a. In that case what is its name, and who is the supplier?
9. Are you currently considering changing/upgrading your CMMS system?
    a. In that case, what system(s) are you looking at?

Part 2

If you were in the situation of acquiring, or upgrading to, a new CMMS system, there would be several criteria to consider. On a scale from 1 to 5, where 5 is very important and 1 is not at all important, rate how important the following criteria would be for your plant.

Table E.1 Criteria.

Nr.	Criteria	Description	Importance(1-5)
1	User simplicity	It is easy and fast for the user to enter, retrieve, and report relevant information in the system.	
2	Scheduling	The system has a function for scheduling recurring work orders and other tasks in a satisfying way.	
3	Spare part inventory	The system keeps track of the spare part inventory and related information for example; price, lead time, supplier information and in which machine it is used in.	
4	Spare part purchasing	The system is connected to, and capable of creating purchase orders in the purchasing platform.	
5	Operator access	The operators can initiate work orders in the CMMS system.	
6	System integration	It is possible to connect the CMMS to other IT-systems in the plant, in order to exchange information between them.	
7	Automatic recording	Equipment related information, for example run time or standstills, can automatically be recorded in the system.	
8	Performance monitoring	The system is capable of displaying chosen performance parameters in real-time.	
9	Flexibility	It is possible to customise the user interface layout, in order to fit your specific needs.	
10	Support	Support from the supplier is available and easy to get hold of during normal office hours (Daytime, Monday to Friday).	
11	Report	The system is able to create customised reports, both manually and automatically.	
12	Decision support	The gathered data can be used by the cmms system to create suggestions regarding maintenance decisions.	
13	Equipment data	The system can be used to hold equipment related data in an easy, accessible way. For example; machine type, ID-number, maintenance history, repair books, autonomous maintenance instructions, supplier details, position at plant, guarantee period and safety instructions etc.	
14	Gadgets	Tablets, smartphones or similar can be connected and used by personnel to enter, retrieve, and report relevant information in the system	
15	Total Cost of Ownership	The cost for using the software during its lifespan is as low as possible. Factors like purchase price, implementation costs, support and consulting	

		services are taken into account.	
16	Human Resources	Information about extern and internal personnel (cost, competencies and contact information) is available in the system.	
17	Prioritisation	It is possible to categorise the equipment regarding to how critical it is for the production. Gives input to the planning function.	
18	Work orders	The system supports multiple work order types including reactive, preventive and project.	
19	Scanning	The system supports bar codes scanning or NFC (Near Field Communication)-tags to input information into the system.	
20	Language	The system is available in the local language.	
21	Preventive maintenance	The system can generate a preventive maintenance plan for a given time interval.	

Part 3 – Current situation

Below are a number of statements. Please rate them from 1-5 (1 means that you fully disagree with the statement, 5 means that you fully agree) based on how well they describe your current circumstances.

Table E.2 Statements about the sites current circumstances.

Statement	Fully Disagree 1	2	3	4	Fully Agree 5
TPM is an important part of our efficiency improving initiatives					
The current system is user friendly and easy to handle					
Operators, supervisors and maintenance personnel are used to handling computers					
The operators are taking part in the autonomous maintenance					
No maintenance is undertaken without a work order					
All maintenance activities performed are logged in the system					
Time spent handling work orders is a notable part of a managers workload					
The information reported in the work orders, for example time spent on the repair, is relevant and accurate					
The preventive maintenance is based on the instruction books and experience rather than statistics.					
The CMMS system is used in planning the preventive maintenance					
Time spent on reactive and preventive maintenance is continuously monitored and followed up					
Performance indicators like MTBF (Mean Time Between Failure) and MTTR (Mean Time To Repair) are measured and followed up					
The information needed to calculate the OEE of machines is collected and monitored.					
It is easy to get relevant reports from the system.					
The maintenance cost for each machine is easy to find.					
The maintenance history for each machine is stored.					
The data recorded in the system regarding each machine is periodically reviewed.					
The spare part inventory is being managed.					
The CMMS system provides assistance in determining which spare parts to keep in stock.					
All of the functions available in the CMMS system are frequently used					

Part 4

Is there anything else you would like to bring up, or do you have any comments on the survey?

Appendix F – Answers to survey

Below are the answers for each survey question presented, see figure F.1 – F.17. Some questions has been anonymised.

Name:		
Answer Options		Response Count
		24
	answered question	24
	skipped question	0
Number	Response Date	Response Text
1	dec 3, 2015 3:25 AM	
2	nov 26, 2015 11:11 AM	
3	nov 23, 2015 3:04 PM	
4	nov 23, 2015 1:36 PM	
5	nov 19, 2015 4:57 PM	
6	nov 19, 2015 10:42 AM	
7	nov 19, 2015 10:07 AM	
8	nov 19, 2015 9:58 AM	
9	nov 16, 2015 11:17 AM	
10	nov 13, 2015 2:10 PM	
11	nov 13, 2015 5:39 AM	
12	nov 13, 2015 2:57 AM	
13	nov 11, 2015 2:43 PM	
14	nov 11, 2015 11:19 AM	
15	nov 11, 2015 10:55 AM	
16	nov 11, 2015 2:48 AM	
17	nov 11, 2015 2:23 AM	
18	nov 10, 2015 12:52 PM	
19	nov 10, 2015 11:29 AM	
20	nov 10, 2015 12:30 AM	
21	nov 9, 2015 3:51 PM	
22	nov 9, 2015 1:58 PM	
23	nov 9, 2015 1:52 PM	
24	nov 9, 2015 1:12 PM	

Figure F.1 Name

Position:		
Answer Options		**Response Count**
		24
	answered question	24
	skipped question	0

Number	Response Date	Response Text
1	dec 3, 2015 3:25 AM	TPM engineer and Acting maintenance supervisor
2	nov 26, 2015 11:11 AM	MAintenance Manager
3	nov 23, 2015 3:04 PM	maintenance deputy
4	nov 23, 2015 1:36 PM	plant manager
5	nov 19, 2015 4:57 PM	Engineering, Facility, EH&S Manager
6	nov 19, 2015 10:42 AM	MAINTENANCE SUPERVISOR
7	nov 19, 2015 10:07 AM	Lead Mechanical Engineer
8	nov 19, 2015 9:58 AM	plant manager
9	nov 16, 2015 11:17 AM	Engineering & Maintenance Manager
10	nov 13, 2015 2:10 PM	Process Engineer
11	nov 13, 2015 5:39 AM	MANAGER - PLANT MAINTENANCE
12	nov 13, 2015 2:57 AM	production manager
13	nov 11, 2015 2:43 PM	Maintenance Manager
14	nov 11, 2015 11:19 AM	ME and technical manager
15	nov 11, 2015 10:55 AM	UH-chef
16	nov 11, 2015 2:48 AM	Maintenance/workshop Engineer
17	nov 11, 2015 2:23 AM	Production Supervisor
18	nov 10, 2015 12:52 PM	Grima
19	nov 10, 2015 11:29 AM	Sr.Manager
20	nov 10, 2015 12:30 AM	Engineering Team Leader
21	nov 9, 2015 3:51 PM	Plant Manager / M3 Project Manager
22	nov 9, 2015 1:58 PM	Maintenance Manager
23	nov 9, 2015 1:52 PM	Plant Engineer
24	nov 9, 2015 1:12 PM	Production manager

Figure F.2 Position of the respondent.

Business area:		
Answer Options	**Response Percent**	**Response Count**
Coated Systems	8,3%	2
Industrial Solutions	45,8%	11
Offshore and Construction	12,5%	3
Sealing Solutions	25,0%	6
Wheel Systems	8,3%	2
	answered question	24
	skipped question	0

Figure F.3 Business areas

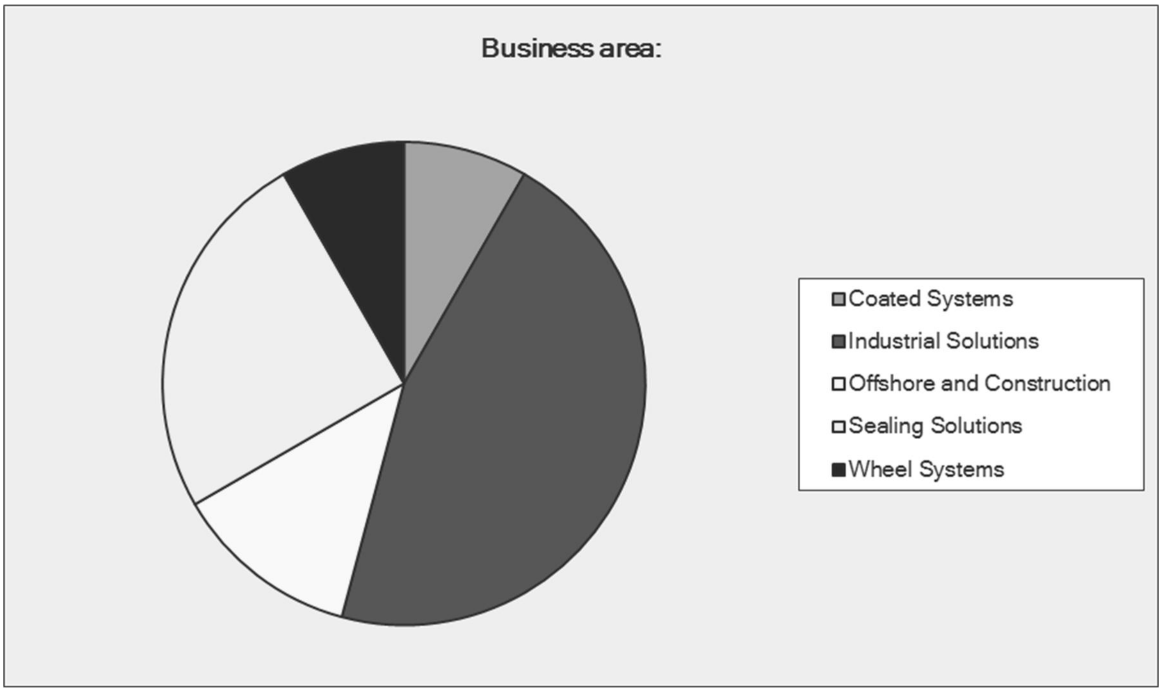

Figure F.4 Pie chart business area

How many blue collar staff are working at the plant?		
Answer Options		Response Count
		24
	answered question	24
	skipped question	0
Number	Response Date	Response Text
1	dec 3, 2015 3:25 AM	297
2	nov 26, 2015 11:11 AM	40
3	nov 23, 2015 3:04 PM	16
4	nov 23, 2015 1:36 PM	167
5	nov 19, 2015 4:57 PM	95
6	nov 19, 2015 10:42 AM	140
7	nov 19, 2015 10:07 AM	38
8	nov 19, 2015 9:58 AM	40
9	nov 16, 2015 11:17 AM	393
10	nov 13, 2015 2:10 PM	62
11	nov 13, 2015 5:39 AM	114
12	nov 13, 2015 2:57 AM	53
13	nov 11, 2015 2:43 PM	70
14	nov 11, 2015 11:19 AM	136
15	nov 11, 2015 10:55 AM	90
16	nov 11, 2015 2:48 AM	88
17	nov 11, 2015 2:23 AM	2
18	nov 10, 2015 12:52 PM	440
19	nov 10, 2015 11:29 AM	60
20	nov 10, 2015 12:30 AM	25
21	nov 9, 2015 3:51 PM	140
22	nov 9, 2015 1:58 PM	176
23	nov 9, 2015 1:52 PM	61
24	nov 9, 2015 1:12 PM	25

Figure F.5 How many blue collar staff are working at the plant?

How many persons are working in maintenance? (If using external contractors, how many are performing maintenance at the plant on daily				
Answer Options		Response Count		
		24		
	answered question	24		
	skipped question	0		
Number	Response Date	Response Text	Internal	External
1	dec 3, 2015 3:25 AM	17	17	0
2	nov 26, 2015 11:11 AM	3	3	0
3	nov 23, 2015 3:04 PM	me and one , (one external daily)	2	1
4	nov 23, 2015 1:36 PM	21	21	
5	nov 19, 2015 4:57 PM	4	4	
6	nov 19, 2015 10:42 AM	8	8	
7	nov 19, 2015 10:07 AM	3	3	
8	nov 19, 2015 9:58 AM	1	1	
9	nov 16, 2015 11:17 AM	31	31	
10	nov 13, 2015 2:10 PM	3	3	
11	nov 13, 2015 5:39 AM	10 to 15 persons including external contractors		
12	nov 13, 2015 2:57 AM	3		
13	nov 11, 2015 2:43 PM	4		
14	nov 11, 2015 11:19 AM	9 employees		
15	nov 11, 2015 10:55 AM	4 to 5		
16	nov 11, 2015 2:48 AM	13		
17	nov 11, 2015 2:23 AM	1		06-apr
18	nov 10, 2015 12:52 PM	25		
19	nov 10, 2015 11:29 AM	3		
20	nov 10, 2015 12:30 AM	3		
21	nov 9, 2015 3:51 PM	12		
22	nov 9, 2015 1:58 PM	7		
23	nov 9, 2015 1:52 PM	6		
24	nov 9, 2015 1:12 PM	3		

Figure F.6 How many persons are working in maintenance?

How much equipment do you have that needs maintenance?		
Answer Options	Response Percent	Response Count
1-50	25,0%	6
51-100	16,7%	4
101-150	16,7%	4
151-200	16,7%	4
201-250	0,0%	0
251-300	4,2%	1
301-350	4,2%	1
351-400	0,0%	0
401-450	0,0%	0
451-500	4,2%	1
501 or more	12,5%	3
	answered question	24
	skipped question	0

Figure F.7 How much equipment do you have that need maintenance?

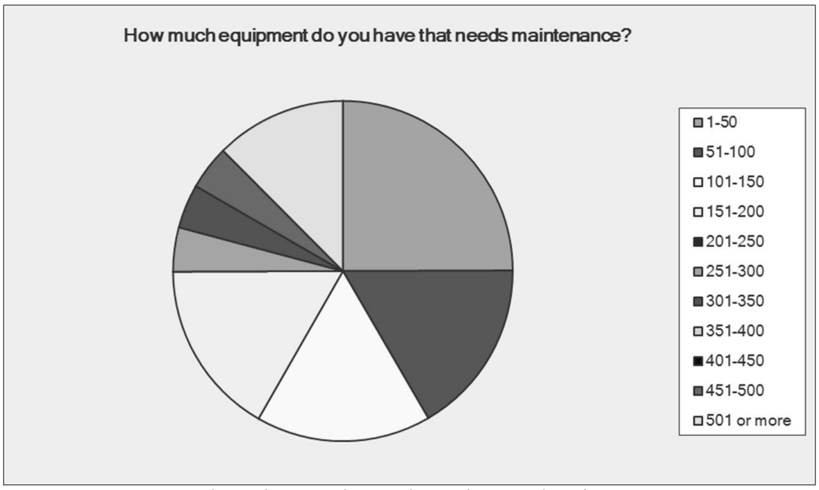

Figure F.8 How much equipment do you have that need maintenance?

How much time is spent on reactive (R) vs. planned (P) maintenance?		
Answer Options	Response Percent	Response Count
R: 100% - P: 0%	0,0%	0
R: 90% - P: 10%	0,0%	0
R: 80% - P: 20%	8,3%	2
R: 70% - P: 30%	16,7%	4
R: 60% - P: 40%	16,7%	4
R: 50% - P: 50%	4,2%	1
R: 40% - P: 60%	12,5%	3
R: 30% - P: 70%	8,3%	2
R: 20% - P: 80%	20,8%	5
R: 10% - P: 90%	12,5%	3
R: 0% - P: 100%	0,0%	0
	answered question	24
	skipped question	0

Figure F.9 How much time is spent on reactive (R) vs. planned (P) maintenance?

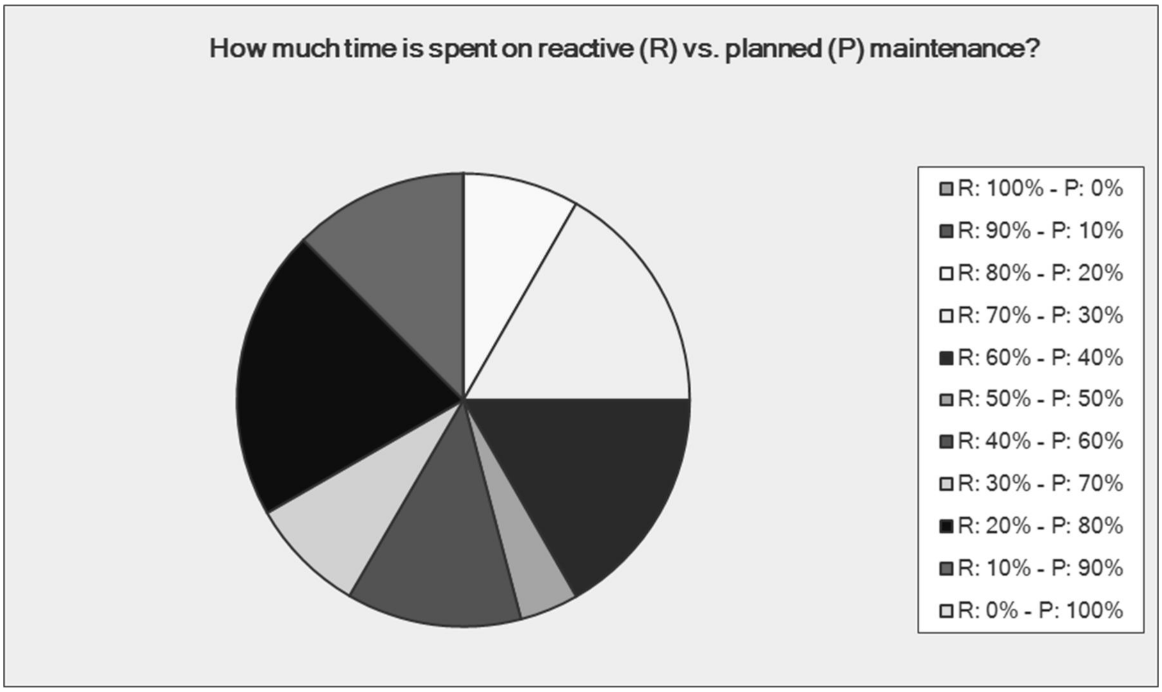

Figure F.10 How much time is spent on reactive (R) vs. planned (P) maintenance?

Do you currently have a Computerised Maintenance Management System (CMMS)*?*A Computerised Maintenance Management System (CMMS) is a software that maintains a				
Answer Options		Response Percent	Response Count	
System name:		100,0%	11	
Supplier:		90,9%	10	
		answered question	11	
		skipped question	13	
Number	Response Date	System name:	Categories	Supplier:
1	nov 23, 2015 1:36 PM	EAM		infor 1.0
2	nov 19, 2015 4:57 PM	COGZ		Cogz International
3	nov 16, 2015 11:17 AM	MCS2000		ESSO SAF groupe ExxonMobil
4	nov 13, 2015 5:39 AM	Optimaint - Enterprise		RANAL SOFTWARE TECHNOLOGIES PVT LTD
5	nov 11, 2015 2:43 PM	Maschinenverwaltung & ALS		Stutz Consulting & ARBURG
6	nov 11, 2015 10:55 AM	CMS		
7	nov 10, 2015 12:52 PM	Maintenance Manager 1.5.8		Amicode
8	nov 10, 2015 12:30 AM	we have put our own system together		Local IT
9	nov 9, 2015 3:51 PM	Frontline Maintenance		Shire Systems
10	nov 9, 2015 1:58 PM	AM-underhåll		Hultin AB Skellefteå
11	nov 9, 2015 1:52 PM	PMC		DPSI

Figure F.11 Do you currently have a CMMS?

Are you currently considering changing or upgrading your CMMS system? If yes, please write the name of system and supplier. If no, please leave				
Answer Options		Response Percent	Response Count	
System		100,0%	2	
Supplier		100,0%	2	
		answered question	2	
		skipped question	22	
Number	Response Date	System	Categories	Supplier
1	nov 16, 2015 11:17 AM	M3		INFOR
2	nov 9, 2015 3:51 PM	Infor M3 Maintenance Module (t		Infor

Figure F.12 Are you currently considering changing or upgrading your CMMS?

Statements								
Answer Options	**1**	**2**	**3**	**4**	**5**	**Rating Average**	**Response Count**	STDAV
TPM is an important part of our efficiency improving initiatives.	0	1	3	5	15	4,42	24	0,862013
The current system is user friendly and easy to handle.	1	2	8	9	4	3,54	24	0,999133
Operators, supervisors and maintenance personnel are used to handling computers	0	3	9	8	4	3,54	24	0,911921
The operators are taking part in the autonomous maintenance.	2	7	8	6	1	2,88	24	1,012949
No maintenance is undertaken without a work order.	4	3	9	3	5	3,08	24	1,320253
All maintenance activities performed are logged in the system.	2	1	3	10	8	3,88	24	1,165933
Time spent handling work orders is a notable part of a managers workload.	0	4	7	7	6	3,63	24	1,033312
The information reported in the work orders, for example time spent on the repair, is relevant and accurate.	2	4	4	6	8	3,58	24	1,320253
The preventive maintenance is based on the instruction books and experience rather than statistics.	0	0	7	7	10	4,13	24	0,832306
The CMMS system is used in planning the preventive maintenance.	5	2	4	3	10	3,46	24	1,580591
Time spent on reactive and preventive maintenance is continuously monitored and followed up.	0	7	0	8	9	3,79	24	1,224037
Performance indicators like MTBF (Mean Time Between Failure) and MTTR (Mean Time To Repair) are measured and followed up.	5	4	4	3	8	3,21	24	1,554006
The information needed to calculate the OEE of machines is collected and monitored.	1	2	2	8	11	4,08	24	1,114929
It is easy to get relevant reports from the system.	5	5	2	8	4	3,04	24	1,428262
The maintenance cost for each machine is easy to find.	8	7	1	5	3	2,50	24	1,443376
The maintenance history for each machine is stored.	0	1	2	7	14	4,42	24	0,81224
The data recorded in the system regarding each machine is periodically reviewed.	1	2	10	7	4	3,46	24	0,999133
The spare part inventory is being managed.	2	5	3	6	8	3,54	24	1,353366
The CMMS system provides assistance in determining which spare parts to keep in stock.	7	5	3	6	3	2,71	24	1,428262
All of the functions available in the CMMS system are frequently used.	9	4	5	4	2	2,42	24	1,351444
						answered question	24	
						skipped question	0	

Figure F.13 multiple chose question regarding statements about the sites current situation. On a scale from 1 to 5, where 5 is fully agree and 1 is fully disagree

Criteria								
Answer Options	1	2	3	4	5	Rating Average	Response Count	standard deviatio
It is easy and fast for the user to enter, retrieve, and report relevant information in the system.	0	0	1	5	18	4,71	24	0,538
The system has a function for scheduling recurring work orders and other tasks in a satisfying way.	0	1	3	8	12	4,29	24	0,841
The system keeps track of the spare part inventory and related information for example; price, lead time, supplier information and in which machine it is used in.	1	1	4	8	10	4,04	24	1,060
The system is connected to, and capable of creating purchase orders in the purchasing platform.	3	6	3	7	5	3,21	24	1,353
The operators can initiate work orders in the CMMS system.	2	5	5	5	7	3,42	24	1,320
It is possible to connect the CMMS to other IT-systems in the plant, in order to exchange information between them.	2	4	7	5	6	3,38	24	1,252
Equipment related information, for example run time or standstills, can automatically be recorded in the system.	2	3	5	3	11	3,75	24	1,362
The system is capable of displaying chosen performance parameters in real-time.	2	2	7	4	9	3,67	24	1,280
It is possible to customise the user interface layout, in order to fit your specific needs.	1	0	8	7	8	3,88	24	1,013
Support from the supplier is available and easy to get hold of during normal office hours (Daytime, Monday to Friday).	0	3	6	6	9	3,88	24	1,053
The system is able to create customised reports, both manually and automatically.	1	1	4	11	7	3,92	24	0,997
The gathered data can be used by the CMMS system to create suggestions regarding maintenance decisions.	1	1	4	11	7	3,92	24	0,997
The system can be used to hold equipment related data in an easy, accessible way. For example; machine type, ID-number, maintenance history, repair books, autonomous maintenance instructions, supplier details, position at plant and guarantee period.	0	1	1	7	15	4,50	24	0,764
Tablets, smartphones or similar can be connected and used by personnel to enter, retrieve, and report relevant information in the system	5	0	6	3	10	3,54	24	1,527
The cost for using the software during its lifespan is as low as possible. Factors like purchase price, implementation costs, support and consulting services are taken into account.	0	2	4	7	11	4,13	24	0,971
Information about extern and internal personnel (cost, competencies and contact information) is available in the system.	2	4	8	5	5	3,29	24	1,207
It is possible to categorise the equipment regarding to how critical it is for the production. Gives input to the planning function.	1	1	4	10	8	3,96	24	1,020
The system supports multiple work order types including reactive, preventive and project.	0	2	6	7	9	3,96	24	0,978
The system supports bar codes scanning or NFC (Near Field Communication)-tags to input information into the system.	5	5	4	6	4	2,96	24	1,399
The system is available in the local language.	2	0	1	3	18	4,46	24	1,154
The system can generate a preventive maintenance plan for a given time interval.	0	0	0	4	20	4,83	24	0,373

Figure F.14 multiple chose questions regarding criteria they would like to have in a new CMMS. On a scale from 1 to 5, where 5 is very important and 1 is not at all important

Is there anything else that you would like to bring up, or do you have any comments on the survey?		
Answer Options		Response Count
		14
	answered question	14
	skipped question	10

Number	Response Date	Response Text
1	dec 3, 2015 3:46 AM	Hope the CMMS systems is better and better
2	nov 23, 2015 3:38 PM	I think that software maintenance is a big help when it is well-designed and well-prepared translation into the language of the country where usage.
3	nov 19, 2015 5:11 PM	The survey is weighted and the results here based on the answers here might not be able to be applied to all locations. An extremely dynamic system that is highly customizable would be a good option to look at. However this type of system does not generate uniformity throughout the organization and tends to be much more expensive.
4	nov 19, 2015 10:22 AM	prio 1 for our needs is simplicity to use. In my opinion, value added activity for a maintenance technician is "putting hands on an equipment to avoid unexpected downtime", non-value added is sitting on a PC or filling a databse with data or . As a lean concept, I would like a CMMS able to reduce non-value added and increase value added. prio 2 is simplicity for installation and adptation to my installed machines. prio 3 is a system able to make activities, plans, results in a VISUAL way, available for anyone in the company, not only maintenance or managers.
5	nov 16, 2015 11:31 AM	Our CMMS is done with using together MCS, M3, Excel !!
6	nov 13, 2015 5:46 AM	1. procurement of Spares: system will trigger the minimum stock, based on which purchasing process will be carried through our ERP software Fourth shift. 2. Language support : we use English as local language support, which can be used by all employees. 3. we have not connected the CMMS software to tablets or mobiles, which is not relevant, as all the systems in our facility is connected to local network, it can be accessed for ticketing from anywhere in the facility. 4. Optimaint software can be accessed only by maintenance staff,we have 4 user licence. Opticomp software can be accessed by all equipment users, which has unlimited access for ticketing (request for maintenance) 5. Barcode scanning we have not used, in CMMS software, which is not relevant for our use.
7	nov 13, 2015 3:24 AM	for maintenance team, spare parts management is very important for us, if the new system can supply competely management even a srcew, i think it will be better
8	nov 11, 2015 3:09 PM	System based preventive mainenace is allways payed back.
9	nov 11, 2015 2:50 AM	If install CMMS in our plant will help to improved maintenance work more efficiency.
10	nov 10, 2015 1:00 PM	A hand over feature should also be included in the system. If an employee finishes his shift but his job is not yet finished and he hands it over to his colleague in the next shift, this should be traceable from the system.
11	nov 10, 2015 11:40 AM	At present in our plant we don't have CMMS, however we have answered the criteria considering importance of the same.
12	nov 10, 2015 12:45 AM	As we have a small plant and do not run more than one shift . Our plant does not require a very technical system to run our maintenance program. I have assisted in designing our system to suit our factory and processes. Yes we could improve and yes the extra info would help . How knows what the future will bring?
13	nov 9, 2015 3:57 PM	We are currently moving over to Infor's Maintenance system as part of moving over to Infor's M3 ERP system. This will affect all 10 sites in the BU TAIS.
14	nov 9, 2015 1:59 PM	To fully utilize a CMMS additional resources would be required.

Figure F.15 Is there anything else that you would like to bring up, or do you have any comments on the survey?

Appendix G – Overall Equipment Efficiency

Overall Equipment Effectiveness (OEE) is used to give a company an indication of how well their production utilises its equipment. OEE is considered to be a key performance index for many manufacturing companies and was originated from creating the philosophy of Total Productive Maintenance. The value for OEE is calculated through multiplying the three factors for Availability, Performance and Quality.

$$OEE = Availibility * Preformance * Quality$$

The OEE-value increases by eliminating or reducing some of the six major causes of loss within a manufacturing site. Those six major losses are considered to be breakdowns, set-ups, small stops, reduced speed, start-up rejects and production rejects (Peters, 2006). Below are each factor explained further.

The availability factor is calculated through subtracting the time wasted on shutdown losses and other major stoppage losses from the total calendar time and then dividing it with the total calendar time. The result is then multiplied by 100 in order to get it in percentage points. This gives an indication of the stoppage effects the production at the site.
(Suzuki, 1994).

$$Availability = \frac{Calender\ time - (shutdown\ loss + major\ stoppage\ loss)}{Calender\ time} * 100\ (\%)$$

The performance factor is calculated as the fraction between the average actual production rate and the standard production rate. The result is then also multiplied by 100 to get it expressed as percentage points. The standard production rate is decelerated as the ideal rate that the plant is design to produce at. With regards to different processes the result will be quantified in different units. (Suzuki, 1994)

$$Preformance = \frac{Average\ actual\ production\ rate}{Standard\ production\ rate} * 100(\%)$$

$$Average\ actual\ production\ rate = \frac{Actual\ production\ rate}{Operation\ time}$$

The factor regarding quality is calculated through subtracting the number of losses from quality defects and reprocessing and then dividing the result with the total production quality (Suzuki, 1994).

$$Quality\ rate = \frac{Production\ quantity\ (t) - (quality\ defect\ loss + reprocessing\ loss)(t)}{Production\ quantity\ (t)}$$

Appendix H – Explanation of each step in Kans approach

Table H.1 Identify IT functionality requirements (Kans 2008)

Phase	Actions	Purpose
A. Define maintenance purpose and goals	*As maintenance activities must support the company's strategic goals, the maintenance goals and purpose must originate from those in order to be able to support them.*	
	Decompose the overall strategic goals of the company, and the goals of the production into purpose and goals of maintenance	Define maintenance goals and purpose
B. Define current state of maintenance	*In this step, the purpose is to map the current state of maintenance, which is done by describing maintenance strategy, policies, procedures, organisation and decision hierarchy. The maintenance resources available and the IT maturity must also be defined. Once the current state has been defined, it is compared to the stated purpose and goals of maintenance. If they match, step C. will be skipped. If they do not match, step 6 should be undertaken in order to identify improvements*	
	Define maintenance organisation and decision hierarchy	Understand how maintenance work is structured
	Define maintenance strategy, policies and procedures	How maintenance is planned, carried out and
	Map the maintenance work process with the help of flow charts, process diagrams etc.	To understand how the maintenance is carried out on an operational level
	Analyse percentage distribution of policies (corrective, preventive and condition-based)	Identify the main maintenance concepts applied, as well as the policies and strategies used
	Review equipment related- (work instructions, technical analyses on equipment etc.) and strategic documentation (maintenance and quality policy, strategy and certifications	Understand what requirements the machines have from maintenance, both from a function and certification point of view
	Review man hours, competence, technology and budget of the maintenance department	Identify the resources currently used in maintenance
	Gather information about current IT support present, and how it is utilised	To define the IT maturity of the plant
C. Identify possible improvements	*In order to incorporate the improvements in the procurement process, the desired state of maintenance must be determined, or else the output of the process will be directed towards the current (non-satisfying) state.*	
	Apply seven management tools, SWOT or other process improvement tools	Identify possible process improvements
	Apply Failure mode effect and critical analysis (FMECA)	To find suitable maintenance policies and define main maintenance strategy
D. Identify IT functional requirements	*The purpose of the final phase is to, based on how the company works and wants to work with maintenance, determine which CMMS functionality and characteristics supports the maintenance work. A matrix similar to table 9 could be used to help in this process.*	
	Define maintenance goals, purposes and utilisation of the CMMS on the different levels of use (strategic, tactical and operational)	Define who will use the system and how it will be used
	Identify users and their goals	Understand what needs the different users of the system has, in order to make sure the system support maintenance operations at every level
	Transfer the identification to IT functionality and characteristics. Input from standards (EN 13306 or 13460), CMMS literature, surveying current available CMMS systems, or use of consultants	Define which functions are needed from a CMMS system

Appendix I – Need identification process

The process was developed to act as a guideline for any industrial group that is considering a standardisation of CMM-systems. It is based on current theory on determining CMMS requirements at a single plant, but has been modified according to the output of the analysis in order to fit in a group context. The existing theory was rather vague on how to turn the data gathered into an actual need specification that would be useful in a procurement, therefore the process incorporates a firm step-by-step procedure of turning raw-data into needs.

The philosophy of the process originated from Kans (2008) application of DeLone and McNeils (2003) in a maintenance management context, and is that “in order for a CMMS to be successful it must fit both a group’s present- and future situation”. In line with this philosophy the data gathering starts at group level, as it is here the overall strategies are set and many of the efficient improvement initiatives are initiated, which dictates future of the maintenance operations. This is also done first in order for the project group to get an understanding of where the maintenance operations are heading, which creates a better context when gathering the operational data. Subsequently, data from the sites is gathered as their needs and opinions are just as important as the groups. If the system does not support the way of working at the plants today the risk is that instead of improving the efficiency, it will decrease it. Likewise, as the maintenance operations at the sites matures and the group initiatives are embraced more, the system must be able to support that as well.

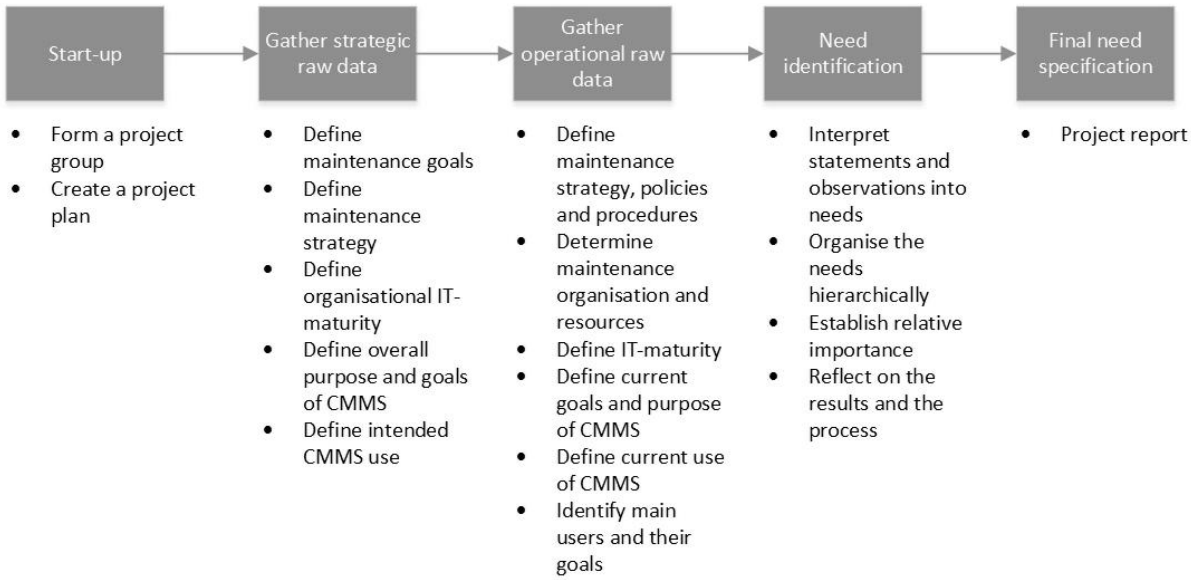

Figure I.1 Need identification process

Start-up

The process should be initiated at group level when considering the possibility of finding a standardised CMMS to be used within the group. This process will not give a simple answer to the question, but it will determine the needs that such a system should satisfy.

Figure I.2 Start-up phase

Form a project group

The need identification process is both complex and not an exact science, therefore the output might differ slightly depending on who performs the elicitation. To cope with this the project group should preferably be comprised of people with different backgrounds and functions. The number of group members can vary, but preferably around 4-5 people from different disciplines. It is recommended to try to involve people with experience or knowledge in the following areas;

- Group strategy
- Efficiency improvement activities
- IT-systems
- Maintenance or production

A final consideration is to assure that the group members has appropriate knowledge in TPM and CMMS.

Create a project plan

Once the team has been assembled, a project plan should be created with a clear purpose, scope, objectives, time-plan etc. At this point it is also a good idea to start considering how many (or all?) plants to visit, and how to decide which of them to target in order to get the most useful information. Once chosen the plants should be contacted as soon as possible to ensure that a visit can be scheduled according to the time-plan.

Gather strategic raw data

Once the start-up phase has been completed, the gathering of strategic raw data can begin. The strategic data should be gathered at group level, mostly through interviews and reviewing strategic documentation. Some of the definitions asked for in this phase might already be stated, in that case a new definition does not need to be created.

Figure I.3 Gather strategic raw phase

Define maintenance goals

Start with defining the organisations goals, it could be done by describing the organisations overlaying purpose with its existence on long term bases, as supporting those should be the purpose of getting a maintenance system in the first place.

Once those goals are defined, the goals for the group be should be decomposed into overall operational goals. It could be done through reflection over the groups actual intention and concretely describe the steps that are needed to take in order to achieve the purpose of the organisation.

The organisational and operational goals should then be decomposed into purpose and goals of maintenance. For example, if the group goal is long term profitability that can be decomposed into having efficient operations in order to keep the operating margin positive, even during recessions. Consequently, one of the maintenance purposes should be to support efficient operations. A maintenance goal derived from that purpose can for example be to achieve an average OEE of 80%. The group's purpose of maintenance should describe why maintenance is of interest, and its goals are an indicator of what can be achieved.

Define maintenance strategy

Once the maintenance goals and purpose has been stated, the next step is determining the strategy of achieving them. There are different ways of doing so, but a commonly maintenance philosophy is TPM. It is a generic approach to maintenance management, but as with any general philosophy it is not sure that all components fit the group's way of working. Therefore, the group must study and analyse the TPM philosophy and then implement those activities that will help them to achieve their goals effectively and efficient.

Define organisational IT-maturity

The organisational IT-maturity refers to both the available IT-infrastructure and how well other systems are utilised. If there has been any other IT-systems that has been standardised, evaluate the success of those and the process of choosing the systems. Different CMMS suppliers offer different solutions regarding hosting and connection between sites, as well as different complexity for their systems. In order to understand the group specific needs, these factors must first be determined.

Define overall purpose and goals of a CMMS

Based on the maintenance goals, purpose and strategy defined in the earlier steps, define the purpose and goals of having a CMMS. If TPM activities are applied then should it be considered and described how a CMMS should support those activities.

Intended use

When the purpose and goals of a CMMS is determined the next step is to determine how to use the system in order to achieve the goals and purpose.
It can be beneficial to review recent CMMS literature or even visit CMMS suppliers to understand what a modern system is capable of. After that should it be possible to express the purpose and goals of using a CMMS into terms and functions associated with CMMSs.

Implementing new or upgrading an obsolete IT-systems has a great potential for business improvement, but the benefits will greatly diminish, or even turn disadvantageous if not used properly. Defined use can also be useful as guidelines or best-practices for the plants if the process ends up with a standardised system.

Gather operational raw data

The purpose of this phase is to gather information from the plants on their way of working with maintenance today, and to get their input on their needs of a CMMS. It will require data gathering from a number of plants in the group, either by visiting them (recommended) or by sending out a survey. The preferable option, given there is enough time, is to conduct site visits as it facilitates better information gathering. When being on site there is a much better chance of identifying latent needs, that the plants perhaps have, but have a hard time to express.

The following steps should be conducted at each site contacted;

Figure I.4 Gather operational raw phase

Define maintenance strategies, policies and procedures

The purpose of this step is to understand how maintenance is planned, carried out and followed up at the sites. If performing site visits: map the maintenance work process with the help of flow charts, process diagrams or equivalent. Analyse the percentage distribution of policies (reactive vs. preventive). Additionally, gather information about the number of equipment that needs maintenance, number of employees and any special process requirements.

Define maintenance organisation and resources

The next step is to determine the maintenance organisation and its decision hierarchy, preferable visualised with a tree diagram. Important factors to consider are whether there is an appointed maintenance manager, and if there are any external personnel on regular basis. Maintenance resources of interest are for example; man hours, competences, budget and technology assets such as IT-systems and hardware.

Define IT-maturity

An IT-system is only as good as its user, so in order to determine what is feasible to use in the plants, an assessment of the current IT-competency is necessary. Factors to evaluate to help in the process;

- Current IT-system used in the production
- How well are those utilised?
- Do the personnel have any problem using the systems?
- What is the general IT-skills of the population in the country?

Define current purpose and goals of CMMS

For the sites currently using a CMMS (or some other system for managing maintenance operations), determine the purpose and goals of using it.

Identify main users and determine their goals

Based on the intended use defined at group level, define who will be frequent users of the system. The defined users should be grouped together with the employees which have the same position. If a standardisation is deemed feasible they will be the people interacting with the system on a daily basis, and therefore their opinion will be an important part of the need identification process.

Need elicitation

Once the raw data has been gathered on both group and plant level the process of turning statements and observations into actual needs, starts.

Figure I.5 Need elicitation phase

Interpret statements and observations into needs

Go through the statements, observations and raw data which are gathered in the previous steps and identify anything that has to be taken into consideration when evaluating a CMMS. Express these as written need statements, where each factor may be translated into any number of customer needs. Make sure to keep track of which needs originates from group level data, and which is from the plants. Below are guidelines for the process, the two first are critical to effective translation, while the rest are to ensure a common approach and consistency across all team members.

- **Express the needs in terms what the CMMS has to do, not in terms of how it might to it.** The gathering process tends to yield preferences described as solution concepts or implementation approaches, for example the statement "It would be nice if the maintenance staff could have an iPad with them that is connected to the CMMS for easy reporting" indicates both the use of a certain brand and a strict way of handling it. However, in order to keep the identification process and the potential purchasing process as open as possible, the statements should be expressed in terms independent of a particular situation. According to this the previous statement would be translated to "the CMMS allows portable devices to access the system".

- **Express the needs as specifically as the raw data.** Needs can be expressed at many different levels of detail. To avoid losing information, the need should be expressed as detailed as the raw data. Using the iPad statement mentioned earlier, that should not be translated to just "it is easy to report in the CMMS", because then the portable dimension is lost.

- **Use positive, not negative, phrasing.** If the needs are expressed as a positive statements, the translation from needs to a CMMS specification is easier. However, positive phrasing might not always be possible for certain needs, in that case this guideline can be disregarded.

- **Express the need as an attribute of the CMMS.** By describing the needs as statements about the system, consistency is assured, which in turn facilitates the translation from needs to specification. Some needs might be difficult to express cleanly as attributes, but in most of these cases the need can be expressed as the attributes of the product user.

- **Avoid the words must and should.** These word will create implications of the importance of a particular need, and should be avoided so that it does not affect the proceeding steps. The relative importance will be dealt with in a later stage.

These steps should result in a list of needs that is the collection of all needs elicited from all the raw data collected. Some of the might not be technologically or economically realisable, but at this stage there should be no such limitations. There might also be conflicting needs in this list at this stage, but the team should not try to address them at this point, but merely document them both. The decisions of how to handle conflicting needs, technological or economic are some of the challenges of the potential purchasing process.

Group the needs

The previous step should result in a list of anywhere between 50 to 300 need statements. That amount of detailed information is hard to work with, and needs to be summarised in order to be useful in the following steps. The purpose of this step is to put them into groups, consisting of a set of overall needs, each one being characterised by a set of underlying needs which are similar to each other. If needed the list may be broken down into tertiary needs as well.
The organisation procedure is intuitive, but to ensure rigidity follow the step-to-step process below.

1. **Print or write each need statement on a separate card or self-stick note.** Use different coloured papers in order to separate the needs between group- and plant level.

2. **Eliminate redundant statements.** The cards expressing redundant need statements can be put together and treated as one card, but if the identical need has been interpreted from both group and plant, make sure to note that it covers both. Also make sure not to consolidate needs that are not identical in meaning.

3. **Group the cards according to the similarity of the needs they express.** Attempt to form groups of three to seven cards that express similar needs. The grouping should be done according to the needs that the users view as similar, not what the team see.

4. **For each group, choose a label.** The label should be a need statement itself that summarises all the needs in that group. It can be one of the needs in the group, or can be a new need statement.

5. **Consider creating supergroups consisting of two to five groups.** If there are 20 or less groups, a two-level hierarchy is probably enough. If there are more than 20 groups consider creating supergroups to create a better overview, which creates a third level in the hierarchy. It is done according to the previous grouping steps.

6. **Review and edit the organised need statements.** There is no "right way" to arrange the needs in a hierarchy. Therefore, it is a good idea to at this point consider alternative groupings or labels.

Establish relative importance

The purpose of the needs determined by this process is to provide a foundation for the evaluation of how well different CMMS supports the way the group is working. In order to be able to do well-grounded decisions in the succeeding purchasing process, the relative importance of the needs has to be known. This is best done by conducting further plant surveys and interviews with key people at group level. A general limit of how many needs to ask about are about 50, which should be enough to cover the important ones while ensuring it is not too time consuming. Many needs will also be either obviously important or part of basic CMMS functionality, therefore the scope can be limited to asking about the needs that are contradictory or ones requiring special features.

Reflect on the results and the process

The last part before concluding the final need specification is to reflect, both on the process and its results. While the process of identifying customer needs can be carried out in a structured way, it is not an exact science. The results should be challenged to verify that they are consistent with the information gathered in the previous steps. Below are some questions to assist in the reflection.

- Have we interacted with all functions that will be affected by a CMMS standardisation?
- Are we able to identify latent as well as explicit needs?
- Are there areas of inquiry we should pursue in follow-up interviews or surveys?
- Which of the plants contacted would be good participants in a pilot implementation of a CMMS?
- What do we know that we did not know when we started? Are we surprised by any of the needs?

Appendix J - Application of the process on Trelleborg Group

The developed process is in this chapter applied on Trelleborg group, the process ends with the presentation for the needs which Trelleborg group has on a CMMS.

Start-up

Form a project group

The project group consisted of Simon Östberg and Viktor Nilsson, under the supervision of Victoria Hellström Mader.

Create a project plan

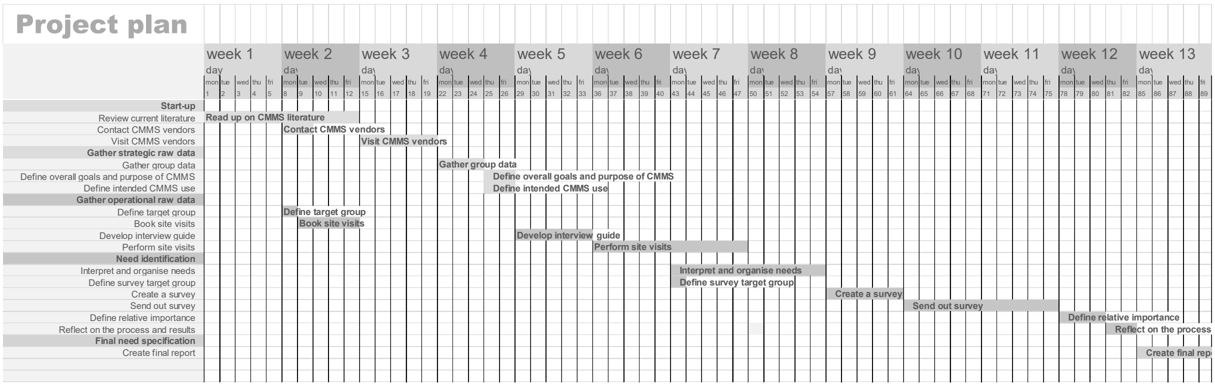

Figure J.1 Project plan for the thesis project.

Gather strategic raw data

Define maintenance goals

Trelleborg are working with an efficiency improvement initiative that they have chosen to call Manufacturing Excellence, with the high-level objectives of; securing customer value and efficiency, while keeping work safety and resource efficiency in focus. This initiative includes several well-known tools, for example 5S, TPM, PSM, JIT and QC story, and emphasises on the synergic benefit of using all of the tools available. The vision is to achieve “four zeros”; zero waste, zero accidents, zero delays and zero defects.

As a part of this initiative, attention has been directed towards maintenance and its importance for efficient operations. This attention is justified by the fact that well-maintained machinery is a crucial component in achieving the vision of the “four zeros”. Consequently, the goal of maintenance has been stated as “Maximise the productions performance by improving the equipment reliability and availability”.

Define maintenance strategy

To reach the maintenance goals, Trelleborg has chosen to pursue a strategy based on their definition of TPM. The strategy revolves around implementing five pillars on site;

1. Eliminating losses (e.g. missing parts, tool changeover, lack of operators, machine stoppage etc.)
2. Implementing autonomous maintenance
3. Implementing scheduled maintenance
4. Train and coach staff (e.g. the operators, maintenance professionals, etc.)
5. Knowledge-building and incorporating all TPM improvements and learnings in the design of new machines.

Eliminating losses revolves around regularly analysing poor OEE performance, and all causes of stoppages, in order to continuously improve the performance. Constant pressure is created to consider any machine stoppage as absolutely unacceptable. The main categories of losses are the following:

- Losses due to:
- Breakdowns
- Changes in sets of tools and adjustments
- Micro-stoppages and idling
- Under-performance
- Non-quality
- Depriving
- Congestion
- Preventive maintenance

Review organisational IT

In the case of Trelleborg Group, there are no standardised production IT-systems in place, therefore no conclusions can be drawn regarding how well such a standardisation works. However, there are standardised administrative systems, whose purchasing process can be useful to draw experience from in a potential CMMS procurement. As Trelleborg is a decentralised group, it has been up to the individual sites to choose their own system, which has led to a large variety of systems present in the group. Any standardised CMMS must be flexible enough to interact with all of these.

There are no policies regarding how a system could be hosted, but central hosting is an option. Regardless of hosting solution, it must be remembered that the point of a CMMS is to build routines around its utilisation, in order to benefit from its superior analysis of data, as well as ensure that all data required is gathered and accurate. If the maintenance process is relying on the CMMS, the system must also be available at all times. Additionally, the latency requirements of a system must also be determined before deciding on how to host the system.

Regarding cloud hosting there is no clear policy about it, but when considering a cloud solution, a number of criteria has to be evaluated;

- Where is the data stored geographically?
- Who owns the data? In case Trelleborg decides to switch supplier
- Is the supplier’s connection fast enough?

Define overall purpose and goals of CMMS
The CMMS is a powerful tool for fully realising the potential of TPM, and since Trelleborg are using that philosophy as a foundation for their strategy, supporting that must be the main purpose of the system. Out of the stated pillars, CMMS can support the following;

1. Eliminating losses
2. Autonomous maintenance
3. Scheduled maintenance
4. Knowledge-building and incorporating all TPM improvements and learnings in the design of new machines.

Consequently, this should be the overall purpose and goals of CMMS

Define intended CMMS use
To support the pillars, and the overall goal of maximising the production systems performance, a CMMS should be used in the following ways:

Table J.1 Intended use compared to TPM-pillars

	Supports pillar			
Intended use	1	2	3	4
Use the work order module to report all maintenance activities	X	X	X	X
Let operators have access to the work order module	X	X		X
Use portable devices for easy reporting	X		X	
Have the CMMS automatically gather data when possible	X		X	X
Analyse the gathered data for problem identifications and follow-ups	X	X	X	X
Have the inventory control module handle the spare parts stock	X		X	
Use the inventory control module to suggest stock levels	X		X	
Register all equipment in the equipment management module		X	X	X
Use the CMMS to store maintenance history for each machine	X			X
Review stored equipment data when considering a new installation	X			X
Use the scheduling and planning module to plan maintenance activities	X		X	
Use the preventive-/predictive maintenance module to generate PM-plans	X		X	
Use the preventive-/predictive maintenance module to, with the help of maintenance data gathered, adjust PM-intervals	X		X	

Gather operational raw data

Define maintenance strategy, policies and procedures
All plants visited had incorporated TPM in some extent in their strategy, and consequently already benefited, or would benefit from a CMMS. However, the use of the system use was limited. The only CMMS-connected pillar in use at all plants was some sort of scheduled maintenance. For a short summary of each plants characteristics and procedures see chapter 4.1 Plant visits.

The survey included a question regarding the distribution of reactive- and preventive maintenance, but the results did not show any uniform approach.

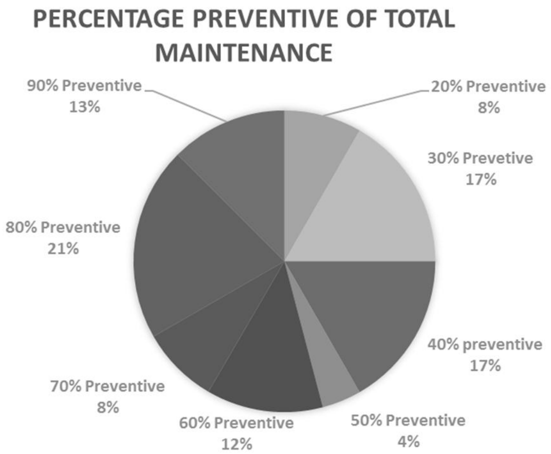

Figure J.2 Amount of preventive maintenance compared to total maintenance

Determine maintenance organisation and resources

The plant visits showed 3/6 plants had an employee managing maintenance on a full-time basis, for the rest of them the task of managing maintenance was just a part the employee's responsibilities. A similar trend was shown in the survey, where about half of the plants had a full-time maintenance manager. Among the surveyed and visited plants, there were 7 of them employing external contractors on a regular basis. Out of the plants visited, only one had a modern CMMS the others had either home-made solutions or obsolete CMM-systems.

The number of employees varied much among the plants, with an average of 115 blue collar staff and 8 people in maintenance (distribution shown below).

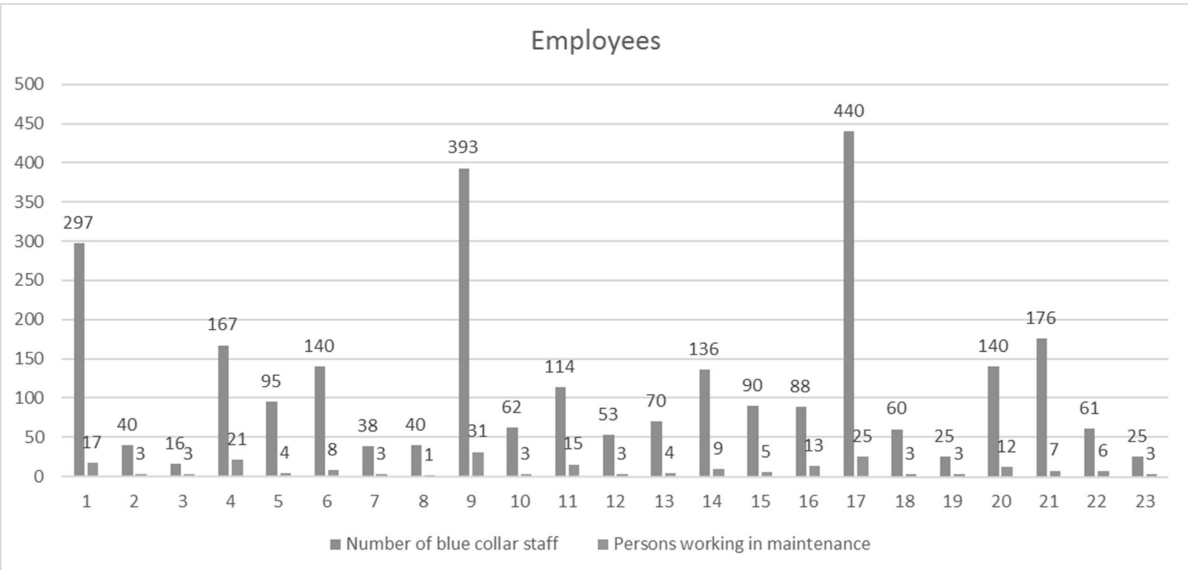

Figure J.3 Numbers of blue collar staff and number of persons working in maintenance

The number of equipment needing maintenance also varied accordingly, and in general there were sites of every size among the surveyed.

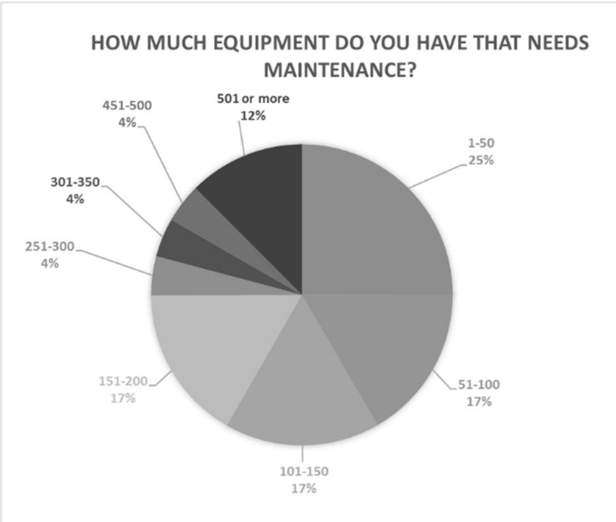

Figure J.4 How much equipment do you have that needs maintenance?

Define IT-maturity

The general IT-knowledge on the sites visited was decent in all cases. Two of the plants were utilising barcode scanning for easier entry of information, and one of them had taken it a step further and were using tablets on the shop floor. All plants had an ERP system, and, they all felt that it was working properly.

The IT-skills among the surveyed sites was of a more varying level as shown below;

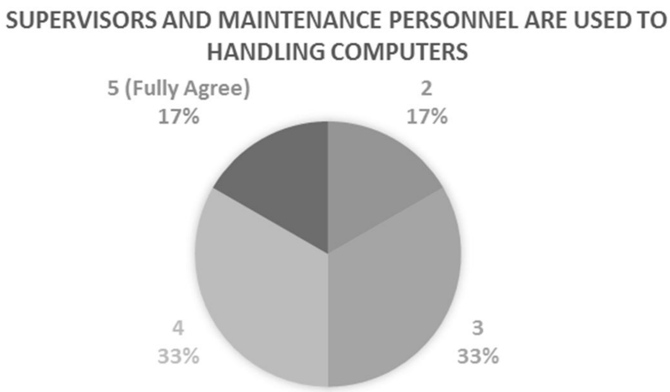

Figure J.5 Operators, supervisors and maintenance personnel are used to handling computers

Define current goals and purpose of CMMS

Since the survey had to be mainly multiple-choice questions, it was hard to let the sites describe their goals and purpose of their system. However, some answers can be derived from the site visit answers.

There seemed to be two explanations to the choice of CMMS, either it was chosen based on what fitted the maintenance department, or the reason behind it had been forgotten with staff turnover. So essentially the goals and purpose of the CMMS was either to support the maintenance operations, or it was unknown. Obviously, not knowing why the system was acquired in the first place makes it hard to know how the system is supposed to be used, and if the system is working good or not (i.e. fulfilling its purpose). In the other cases, the choice was more structured, however it is unsure if the purpose of the system was derived from the operational goals, or plainly was "to support maintenance operations".

The system choice process sheds some light on the question, in plant A and D it was solely chosen by the maintenance department, which most likely means that the acquisition was driven by the maintenance departments need and not a general plant goal. So even in these cases with a semi-structured choice process, it will be hard to determine the system success, since there are no clear goals and purpose to compare to.

Define current use of CMMS

In all cases, the maintenance system was used to assist in PM planning, and for half of them it was actually the only use. Two plants had also incorporated the system to assist in spare part handling, and four were using the machine related information in the system. One of the plants had made a sophisticated, excel-based solution for reporting non-urgent issues in the production. To gather information, 5/6 plants were utilising the work order module (or similar), however only a few of them reported everything.

Table J.2 How the visited plants current use of CMMS

	Plant					
	A	B	C	D	E	F
Maintenance system use	PM planning, Spare part handling, Machine related information	PM planning, Some spart part handling	PM planning	PM planning	PM planning	PM planning, Continious improvement
Data gathering with WO module	x	x	x	x	x	
System holds machine related information	x	x	x		x	
The CMMS registers spare part usage	x	x				

The survey answers regarding the CMMS use has been summarised below.

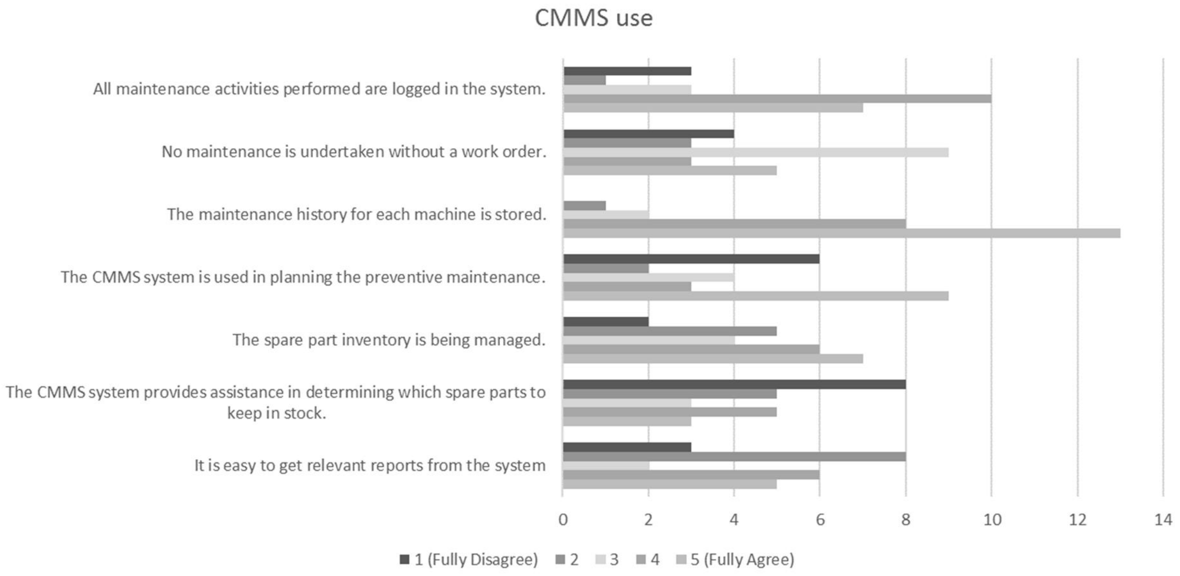

Figure J.6 Summarised answers from the survey regarding the sites use of their CMMS

Identify main users and their goals

Identifying main users is both connected to the current and potential future users of the system. Based on the group strategy, it would be beneficial to let the operators initiate work orders the system, so they have also been taken into consideration in this process. Below are the main users, and their interpreted goals.

- **Maintenance manager**
    - Efficient maintenance operations
    - Have accurate maintenance data available
    - Have the ability to analyse maintenance data
    - Have relevant data for follow-ups
    - Minimise spare part holding costs
    - Be able to generate preventive maintenance plans
    - Keep track of equipment information
    - Be able to determine maintenance cost per machine
- **Maintenance staff**
    - Have instructions and maintenance history easily available
    - It is simple and fast to report work orders
    - Spend as much time as possible working on the equipment
    - Know which spare parts that are in stock
- **Operators**
    - Fast confirmation that the issue has been noted by maintenance personnel
    - It is simple to initiate a work order
    - Possibility to register suggestions

Need identification

Interpret statements and observations into needs

In appendix D is a list of statements gathered from the sites and their interpretation into needs. The interpretation also includes a number of latent needs, which are needs that the interviewed have not expressed clearly, but which the team's observations and intuition see as a need.

Organise the needs in groups

The logic of the grouping was to fit the needs together under topics that has to do with different areas of consideration. The needs that were similar in meaning has been grouped together, but in this chart still shown in *italic,* and the latent needs are marked with (!). The groups are presented below, which statements placed in each group can be seen in appendix D.

- Scheduled maintenance
- Work order handling
- Information storing
- Spare part handling
- Data gathering
- Personnel
- Availability
- Usability
- Continuous improvement
- Analysis
- Benchmarking
- Connectivity

Establish relative importance

At this point of the process, it would have been optimal to send out another survey asking a number of sites to rate the importance of the needs, in order to determine the relative importance. However, due to the tack of time for this project, the relative importance has had to be derived from the survey that was sent out to gather additional information to the research. The result of that ranking is presented below in their corresponding groups. The wide bar represents the average rating, and the standard deviation is shown at the tip of that bar.

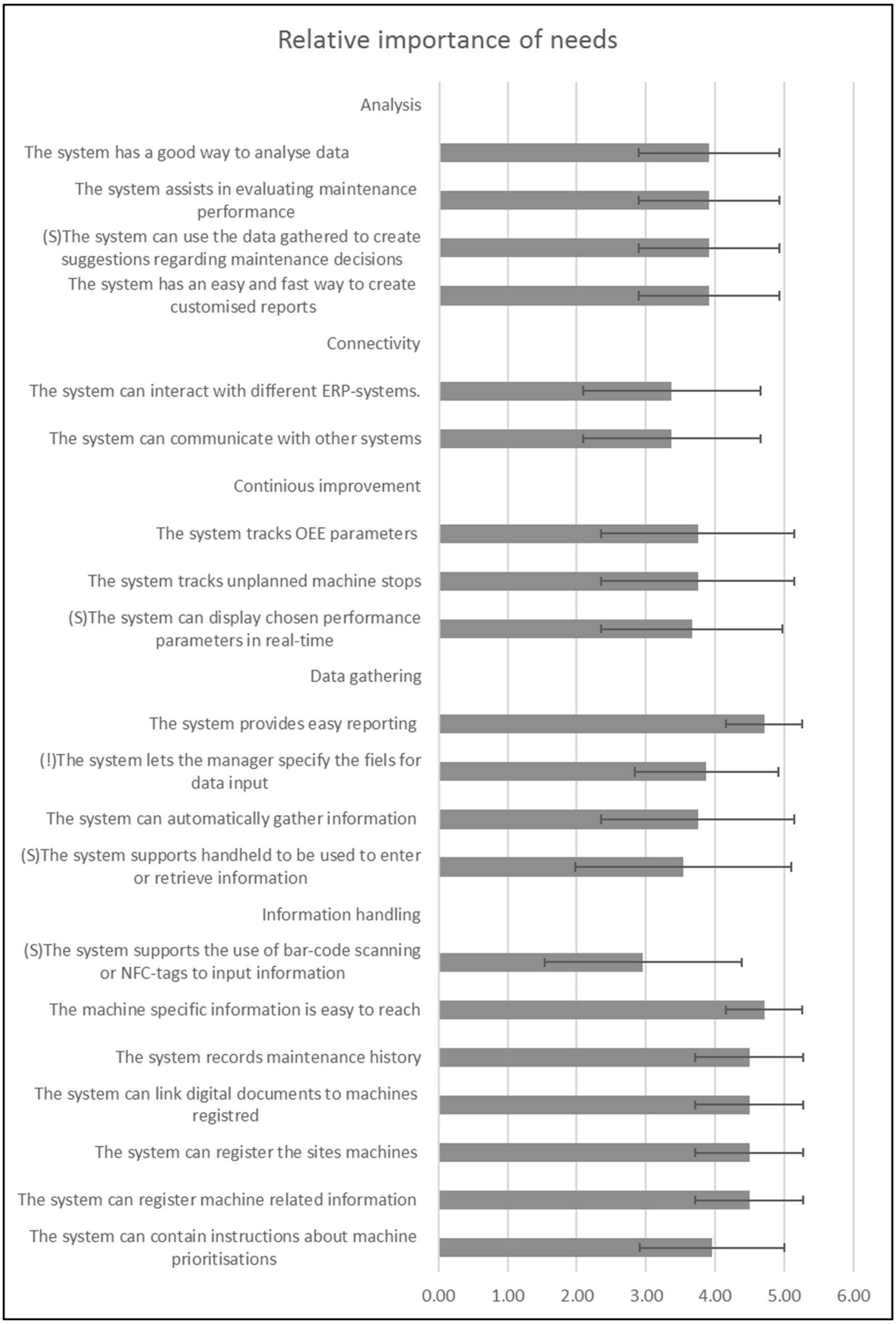

Figure J.7 Relative importance of needs

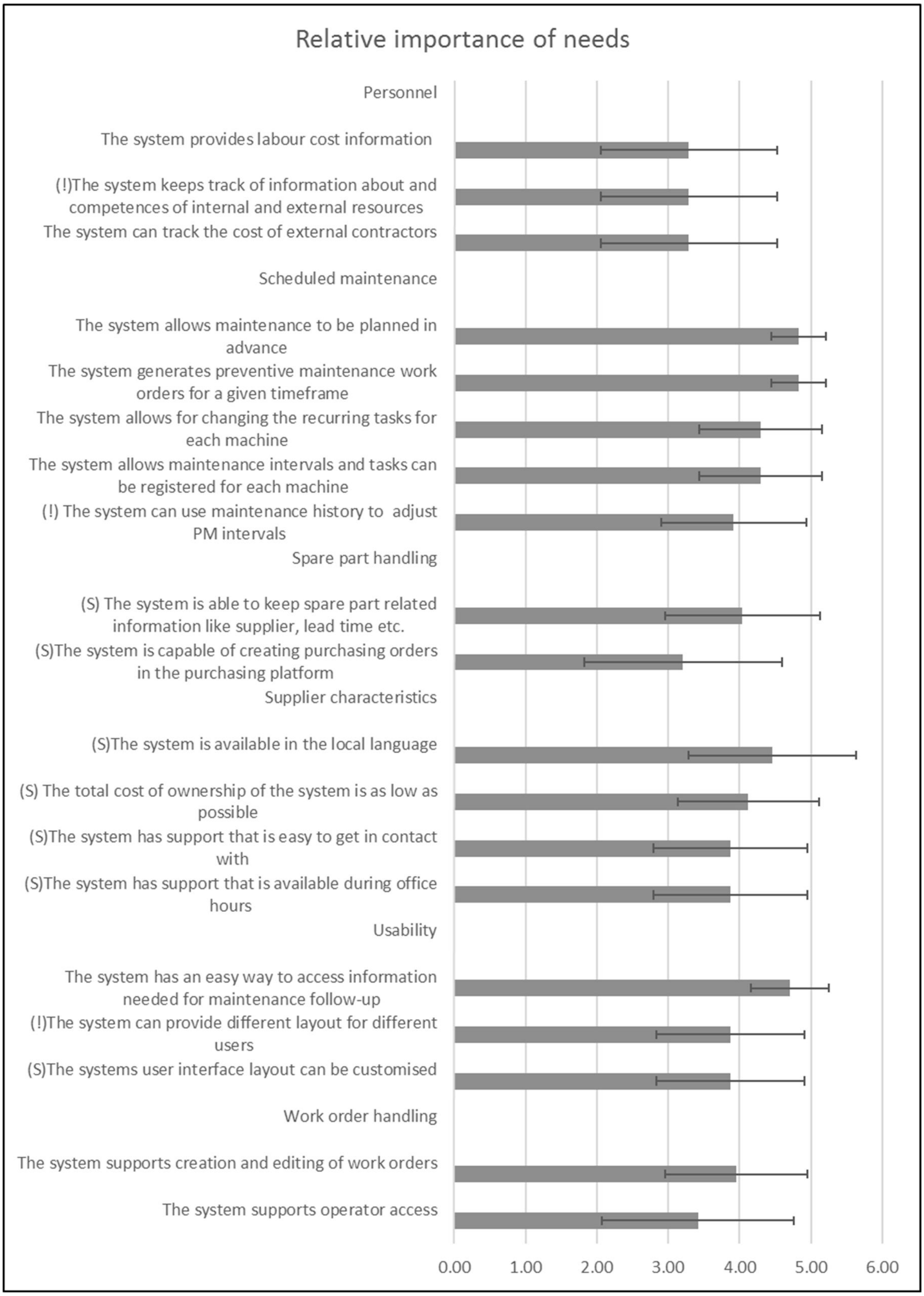

Figure J.8 Relative importance of needs

Reflect on the results of the process
In general, the process would have benefited from a bit more thorough rating of the relative importance. Due to the limited time-frame, and the fact that the need elicitation process only was a part of the whole thesis, it has not been possible. However, the plant needs are just a part of the final specification, and are mainly in place to highlight needs from the plants that cannot be determined through the strategic raw data, and we believe that the most important site needs have been highlighted. To increase rigidity, a second survey containing all the identified needs could be sent out to all plants in the group, asking them to rate the importance of these factors in the same manner the previous survey did.

Based on the first multiple-choice section in the survey, which had the purpose of determining the current way of working, there are some sites that could be considered for a pilot implementation. Those sites have been highlighted since they have rated several maintenance maturity indicators high. The following questions are considered indicators;

- TPM is an important part of our efficiency improving initiatives.
- Operators, supervisors and maintenance personnel are used to handling computers
- The operators are taking part in the autonomous maintenance.
- No maintenance is undertaken without a work order.
- All maintenance activities performed are logged in the system.
- The preventive maintenance is based on the instruction books and experience rather than statistics.
- The CMMS system is used in planning the preventive maintenance.
- Time spent on reactive and preventive maintenance is continuously monitored and followed up.
- Performance indicators like MTBF (Mean Time Between Failure) and MTTR (Mean Time To Repair) are measured and followed up.
- The information needed to calculate the OEE of machines is collected and monitored.
- The maintenance history for each machine is stored.
- The data recorded in the system regarding each machine is periodically reviewed.
- The spare part inventory is being managed.

Among the needs identified, the most surprising was the high importance of language support, as that was a topic that was not at all mentioned in the literature. Likewise, the need for user friendliness was also a highly rated property, and its importance was highlighted in the analysis, but literature does not mention it that much.

Final need specification

To determine which needs to bring into the procurement process, the plant and group needs have been combined in the matrix to both transform the intended use into need statements, and to make sure no needs from the plants are missed. The instances where the plant need coincides with the groups intended use has been marked with “X”, and in those cases the need has been taken into the final specification. Additionally, there are some instances where the plant need is not covered by the groups use, but the need is seen as important. In those cases, it has been marked with a (!). The first two tables presented below are the matrices where the site needs have been combined with the groups intended use. In the cases a relative importance was determined, that was included in the first column after the statement. Which needs that are included in the final specification is marked by "YES" in the rightmost column.

Table J.3 Final need identification

Plant needs / Group intended use	Average rating	Use the work order module to report all maintenance activities	Let operators have access to the work order module	Use portable devices for easy reporting	Have the CMMS automatically gather data when possible	Analyse the gathered data for problem identifications and follow-ups	Have the inventory control module handle the spare parts stock	Use the inventory control module to suggest stock levels	Register all equipment in the equipment management module	Use the CMMS to store maintenance history for each machine	Review stored equipment data when considering a new installation	Use the scheduling and planning module to plan maintenance activities	Use the preventive-/predictive maintenance module to generate PM-plans	Use the preventive-/predictive maintenance module to, with the help of maintenance data gathered, adjust PM-interv	Include? YES/N
Work order handling															
The system supports operator access	**3.42**	X	X												**YES**
The system supports creation and editing of work orders	**3.96**									X					**YES**
The system has a simple way to notify the maintenance staff	-	X	X												**YES**
The system can show that the maintenance personell has noted the issue	-	X	X												**YES**
(!)The system supports attaching additional information to the maintenance request	-	X	X							X					**YES**
(!)The system allow the work load from a work order to be spread between the actors involved.	-														**YES**
Scheduled maintenance															
(!) The system can use maintenance history to adjust PM intervals	**3.92**					X								X	**YES**
The system allows maintenance intervals and tasks can be registered for each machine	**4.29**												X		**YES**
The system allows for changing the recurring tasks for each machine	**4.29**					X							X		**YES**
The system generates preventive maintenance work orders for a given timeframe	**4.83**											X	X		**YES**
The system allows maintenance to be planned in advance	**4.83**											X	X		**YES**
Information storing															
The system can contain instructions about machine prioritisations	**3.96**								X						**YES**
The system can register machine related information	**4.50**								X		X				**YES**
The system can register the sites machines	**4.50**								X		X				**YES**
The system can link digital documents to machines registred	**4.50**			X					X		X				**YES**
The system records maintenance history	**4.50**	X							X	X	X				**YES**
The machine specific information is easy to reach	**4.71**			X					X		X				**YES**
The system allows for updating current machinery	-								X		X				**YES**
The system contains instructions for autonomous maintenance connected to each machine.	-		X						X						**YES**
The system assists in keeping data accurate	-								X		X				**YES**
(!)The system has easy navigation throug the different equipment.	-								X		X				**YES**
Spare part handling															
(S)The system is capable of creating purchasing orders in the purchasing platform	**3.21**						X								**YES**
(S) The system is able to keep spare part related information like supplier, lead time etc.	**4.04**						X	X							**YES**
The system can handle spare part inventory	-						X	X							**YES**
The system enables wieving the spare part inventory of other sites	-						X								**YES**
(!)The system provides expected spare parts demands	-						X	X							**YES**
(!)The system provides spare part re-order points	-						X	X							**YES**
(!)The system keeps track of spare part costs	-						X								**YES**
Data gathering															
(S)The system supports the use of bar-code scanning or NFC-tags to input information	**2.96**			X											**NO**
(S)The system supports handheld to be used to enter or retrieve information	**3.54**			X											**YES**
The system can automatically gather information	**3.75**				X										**YES**
(!)The system lets the manager specify the fiels for data input	**3.88**	X	X												**YES**
The system provides easy reporting	**4.71**	X	X	X											**YES**
The system allows for recording spare parts used	-	X					X	X			X				**YES**
The system supports time-reporting	-	X													**YES**
(!)The system supports reporting in the same extent, independent of who does it	-	X	X												**YES**
The system tracks downtime, costs and spare parts used	-	X				X	X	X	X		X				**YES**

Table J.4 Final need identification

Plant needs / Group intended use	Average rating	Use the work order module to report all maintenance activities	Let operators have access to the work order module	Use portable devices for easy reporting	Have the CMMS automatically gather data when possible	Analyse the gathered data for problem identifications and follow-ups	Have the inventory control module handle the spare parts stock	Use the inventory control module to suggest stock levels	Register all equipment in the equipment management module	Use the CMMS to store maintenance history for each machine	Review stored equipment data when considering a new installation	Use the scheduling and planning module to plan maintenance activities	Use the preventive-/predictive maintenance module to generate PM-plans	Use the preventive-/predictive maintenance module to, with the help of maintenance data gathered, adjust PM-interv	Include? YES/I
Personnel															
The system can track the cost of external contractors	**3.29**					X									**YES**
(!)The system keeps track of information about and competences of internal and external resources	**3.29**											X			**YES**
The system provides labour cost information	**3.29**					X									**YES**
The system can be used by external staff	-	X													**YES**
The system supports invoicing	-														**NO**
Availability															
The system allows multiple users	-	X	X												**YES**
(!)The system is accessible from anywere in the plant	-	X	X	X											**YES**
(!)The system is responsive	-	X	X	X											**YES**
Usability															
(S)The systems user interface layout can be customised	**3.88**		X												**YES**
(!)The system can provide different layout for different users	**3.88**		X												**YES**
The system has an easy way to access information needed for maintenance follow-up	**4.71**					X									**YES**
The system is user-friendly	-														**(!) YES**
(S)The system only displays functions that are used	-		X												**YES**
The system works on office computers	-	X	X												**YES**
Continious improvement															
(S)The system can display chosen performance parameters in real-time	**3.67**				X	X					X				**YES**
The system tracks unplanned machine stops	**3.75**				X	X					X				**YES**
The system tracks OEE parameters	**3.75**				X	X									**YES**
The system allows personnel to report improvement suggestions	-		X			X					X				**YES**
(S)The system can determine MTBF and MTTR for the machines	-					X					X				**YES**
The system tracks maintenance costs per machine	-					X			X	X	X				**YES**
Analysis															
The system has an easy and fast way to create customised reports	**3.92**					X					X				**YES**
(S)The system can use the data gathered to create suggestions regarding maintenance decisions	**3.92**					X									**YES**
The system assists in evaluating maintenance performance	**3.92**					X									**YES**
The system has a good way to analyse data	**3.92**					X					X				**YES**
Benchmarking															
The system supports information sharing with other Trelleborg sites	-														**NO**
Supplier characteristics															
(S)The system has support that is available during office hours	**3.88**														**(!) YES**
(S)The system has support that is easy to get in contact with	**3.88**														**(!) YES**
(S) The total cost of ownership of the system is as low as possible	**4.13**														**(!) YES**
(S)The system is available in the local language	**4.46**														**(!) YES**
Connectivity															
The system can communicate with other systems	**3.38**				X		X								**YES**

Below is the final need specification of which needs that Trelleborg Group have from a CMMS, and comprises of all the needs that was given a “YES” in the previous two tables.

Table J.5 Trelleborg’s needs on a standardised CMMS

CMMS NEEDS
Analysis
The system has an easy and fast way to create customised reports
The system can use the data gathered to create suggestions regarding maintenance decisions
The system assists in evaluating maintenance performance
The system has a good way to analyse data
Availability
The system allows multiple users
The system is accessible from anywere in the plant
The system is responsive
Connectivity
The system can communicate with other systems
Continious improvement
The system can display chosen performance parameters in real-time
The system tracks unplanned machine stops
The system tracks OEE parameters
The system allows personnel to report improvement suggestions
The system can determine MTBF and MTTR for the machines
The system tracks maintenance costs per machine
Data gathering
The system supports handheld to be used to enter or retrieve information
The system can automatically gather information
The system lets the manager specify the fiels for data input
The system provides easy reporting
The system allows for recording spare parts used
The system supports time-reporting
The system supports reporting in the same extent, independent of who does it
The system tracks downtime, costs and spare parts used
Information handling
The system can contain instructions about machine prioritisations
The system can register machine related information
The system can register the sites machines
The system can link digital documents to machines registred
The system records maintenance history
The machine specific information is easy to reach
The system allows for updating current machinery
The system contains instructions for autonomous maintenance connected to each machine.
The system assists in keeping data accurate
The system has easy navigation throug the different equipment.

Table J.6 Trelleborg group’s needs on a standardised CMMS

CMMS NEEDS
Personnel
The system can track the cost of external contractors
(!)The system keeps track of information about and competences of internal and external resources
The system provides labour cost information
The system can be used by external staff
Scheduled maintenance
The system can use maintenance history to adjust PM intervals
The system allows maintenance intervals and tasks can be registered for each machine
The system allows for changing the recurring tasks for each machine
The system generates preventive maintenance work orders for a given timeframe
The system allows maintenance to be planned in advance
Spare part handling
The system is capable of creating purchasing orders in the purchasing platform
The system is able to keep spare part related information like supplier, lead time etc.
The system can handle spare part inventory
The system enables wieving the spare part inventory of other sites
The system provides expected spare parts demands
The system provides spare part re-order points
The system keeps track of spare part costs
Supplier characteristics
The system has support that is available during office hours
The system has support that is easy to get in contact with
The total cost of ownership of the system is as low as possible
The system is available in the local language
Usability
The systems user interface layout can be customised
The system can provide different layout for different users
The system has an easy way to access information needed for maintenance follow-up
The system is user-friendly
The system only displays functions that are used
The system works on office computers
Work order handling
The system supports operator access
The system supports creation and editing of work orders
The system has a simple way to notify the maintenance staff
The system can show that the maintenance personell has noted the issue
The system supports attaching additional information to the maintenance request
The system allow the work load from a work order to be spread between the actors involved.

Appendix K – Interpretation of the needs

Process application data

Table K.1 Interpretation of needs

Question	Interpreted need(s)
How do you identify problems to work with	The system allows personnel to report improvement suggestions
How often are improvements followed up?	The system has an easy and fast way to create customised reports
BA collaboration	
Any collaboration with other plants in BA? If so, which kind?	The system supports information sharing with other Trelleborg sites
	The system enables wieving the spare part inventory of other sites
IT-skills	
What other IT systems do you have?	The system can interact with different ERP-systems.
Autonomous maintenance	
What kind of maintenance work is carried out by the operator?	The system can hold instructions, check-lists, asset data and employee data.
In that case, how are those instructions made?	The system supports entering and deleting information about equipment
In which way is the CMMS used in the work with aut. Maint?	The system contains instructions for autonomous maintenance connected to each machine.
Reactive maintenannce	
How is maintenance staff contacted?	The system has a simple way to notify the maintenance staff
	The system can show that the maintenance personell has noted the issue
	The system can be used to notify the maintenance staff
Is the WO loggen in the system, and how?	The system supports creation and edititing of work orders
Are there any machines that are prioritised for reactive maint?	The system allows the manager to prioritise machines
How do the mainteance staff know which machines are prioritised?	The system can contain instructions about machine prioritisations
Is there something about the logging that could be done smoother?	The system has a fast way to create a request for maintenance
	The system is user-friendly
	The system supports operator access
	The system supports attaching additional information to the maintenance request
Preventive maintenance	
How do you work with preventive maintenance?	The system can register the sites machines
	The system allows maintenance intervals and tasks can be registered for each machine
	The system generates preventive maintenance work orders for a given timeframe
How far in advance is the maintenance planned?	The system allows maintenance to be planned in advance
How do you identify which machines to target, and which actions to do?	The system allows for changing the recurring tasks for each machine
How do you use the CMMS when working with PM?	The system can store recurring work orders for machines
	The recurring service intervals in the system can be modified
Follow-up on maintenance	
What kind of follow-ups do you do on your maintenance performance?	The system assists in evaluating maintenance performance
What perimeters are evaluated	The system tracks unplanned machine stops
	The system tracks OEE
Is the information needed easy to access?	The system has an easy way to access information needed for maintenance follow-up
Do you have any way of tracking each machines maintenance costs?	The system tracks maintenance costs per machine
Are there anything you dont have right no, but would like to evaluate?	The system can automatically gather information
	The system has a tool for analysis
	The system tracks downtime, costs and spare parts used
Personnel and internal/external resources	
Do you have any system for keeping track of internal/external resources, their competencies and their costs?	The system can track the cost of external contractors
How are the maintenance labour costs followed up?	The system provides labour cost information

Table K.2 Interpretation of needs

Question	Interpreted need(s)
Information handling	
How do you handle machine-related info?	The system can link digital documents to machines registred
	The system records maintenance history
What information is stored for each machine?	The system can register machine related information
What is the stored data used for?	The machine specific information is easy to reach
Do you feel that you are missing any data regarding the machines?	The system tracks OEE parameters
Who is responsible for keeping this info accurate?	The system assists in keeping data accurate
How often is this info reviewed?	The system assists in updating machine related information
Data gathering	
In which instances is new information entered into the system?	The system can register new machines
	The system allows for updating current machinery
	The system support work orders
What is entered, and who is responsible for doing it?	The system can register chosen details for a work order
How is it entered(portable device, computer etc?)	The system works on office computers
What kind of data is automatically gathered from the equipment	The system supports automatic data gathering
	The system can communicate with other systems
Do you experience any problems with the current way of entering information	The system provides easy reporting
Spare parts handling	
How do you keep track of the spare part inventory?	The system handles spare part inventory
Does it record history of spare parts used for the equipment?	The system allows for recording spare parts used
General CMMS questions	
Why did you choose the current system?	The system is easy to work with
How many users do you have in your system?	The system allows multiple users
	The system can be used by external staff
Functionality	
What do you think works well with the system you are using?	The system is easy to use
	The system is intuitive
	The system keeps a job until It is finished
Which of all the available functions in the CMMS are you using?	The system supports PM
	The system supports time-reporting
	The system supports invoicing
	The system supports spare parts handling
	The system stores equipment history
Are there any functions that you do not use?	The system only displays functions that are used
Are there any features you wish you had in the CMMS?	The system has a good way to analyse data
	The system has a fast way to input data
	The system can handle spare parts

Table K.3 Interpretation of needs

Latent needs
The system automatically tracks the machine performance
The system lets operators create work orders
The system supports reporting in the same extent, independent of who does it
The system is accessible from anywere in the plant
The systan can automatically record equipment performance
The system can use maintenance history to adjust PM intervals
The system allows for scheduling work orders
The system automatically records machine performance
The system assists in keeping data accurate
The system lets the manager specify the fiels for data input
The system has easy navigation throug the different equipment.
The system allow the work load from a work order to be spread between the actors involved.
The system keeps track of information about and competences of internal and external resources
The system provides expected spare parts demands
The system provides spare part re-order points
The system keeps track of spare part costs
The system can provide different layout for different users
The systems user interface layout can be customised
The system supports handheld to be used to enter or retrieve information
The system can use the data gathered to create suggestions regarding maintenance decisions

Grouping the needs

Table K.4 Grouping of needs

Scheduled maintenance	
The system generates preventive maintenance work orders for a given timeframe	
	The system supports preventive maintenance
The system allows maintenance to be planned in advance	
	(!)The system allows for scheduling work orders
The system allows maintenance intervals and tasks can be registered for each machine	
	The system can store recurring work orders for machines
The system allows for changing the recurring tasks for each machine	
	The recurring service intervals in the system can be modified
(!) The system can use maintenance history to adjust PM intervals	
Work order handling	
The system has a simple way to notify the maintenance staff	
	The system has a fast way to create a request for maintenance
	The system can be used to notify the maintenance staff
The system can show that the maintenance personell has noted the issue	
	The system support work orders
The system supports creation and edititing of work orders	
The system supports operator access	
	(!)The system lets operators create work orders
The system supports attaching additional information to the maintenance request	
	The system can register chosen details for a work order
The system keeps a job until it is finished	
(!)The system allow the work load from a work order to be spread between the actors involved.	

Table K.5 Grouping of needs

Information storing	
The system can register machine related information	
	The system can hold instructions, check-lists, asset data and employee data.
	The system can register new machines
The system allows for updating current machinery	
	The system supports entering and deleting information about equipment
The system contains instructions for autonomous maintenance connected to each machine.	
The system can register the sites machines	
The system can contain instructions about machine prioritisations	
	The system allows the manager to prioritise machines
The system can link digital documents to machines registred	
The system records maintenance history	
	The system stores equipment maintenance history
The machine specific information is easy to reach	
The system assists in keeping data accurate	
	The system assists in updating machine related information
	(!)The system assists in keeping data accurate
(!)The system has easy navigation throug the different equipment.	
Spare part handling	
The system can handle spare part inventory	
	The system supports spare parts handling
	The system can handle spare parts
The system enables wieving the spare part inventory of other sites	
(!)The system provides expected spare parts demands	
(!)The system provides spare part re-order points	
(!)The system keeps track of spare part costs	
Data gathering	
The system allows for recording spare parts used	
The system can automatically gather information	
	The system supports automatic data gathering
	(!)The system automatically tracks the machine performance
	(!)The systan can automatically record equipment performance
	(!)The system automatically records machine performance
The system provides easy reporting	
	The system has a fast way to input data
The system supports time-reporting	
(!)The system supports reporting in the same extent, independent of who does it	
(!)The system lets the manager specify the fiels for data input	
The system can collect the data needed for OEE calculation	
The system tracks downtime, costs and spare parts used	
The system supports handheld to be used to enter or retrieve information	
Personnel	
The system can track the cost of external contractors	
The system provides labour cost information	
(!)The system keeps track of information about and competences of internal and external resources	
The system can be used by external staff	
The system supports invoicing	

Table K.6 Grouping of needs

Availability	
The system allows multiple users	
(!)The system is accessible from anywere in the plant	
(!)The system is responsive	
Usability	
The system is user-friendly	
	The system is easy to work with
	The system is easy to use
	The system is intuitive
The system has an easy way to access information needed for maintenance follow-up	
The systems user interface layout can be customised	
(!)The system can provide different layout for different users	
The system only displays functions that are used	
The system works on office computers	
Continious improvement	
The system allows personnel to report improvement suggestions	
The system tracks unplanned machine stops	
The system tracks OEE parameters	
	The system tracks OEE
The system tracks maintenance costs per machine	
Analysis	
The system assists in evaluating maintenance performance	
The system has a good way to analyse data	
	The system has a tool for analysis
(!)The system can use the data gathered to create suggestions regarding maintenance decisions	
The system has an easy and fast way to create customised reports	
Benchmarking	
The system supports information sharing with other Trelleborg sites	
Connectivity	
The system can interact with different ERP-systems.	
The system can communicate with other systems	