Juha Järvinen

# Scalable Maintenance Model

## Case Kekkilä-BVB

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Competing this Master´s thesis study has been a great journey in every sense. It felt like a marathon-like challenge, where the finish line seemed almost unreachable at first. Still, step by step the thesis progressed and finally the finish line was reached. All the knowledge and skills learned during the journey helped to draw a roadmap from one checkpoint to the next, allowing me eventually to reach the finish line. Now on the podium, I want to take this opportunity to acknowledge those people without whom I would not have achieved the ultimate goal.

I am sincerely grateful to my employer Kekkilä-BVB for enabling my Master´s studies and special thanks to my superior Mr. Jukka Merta for setting the business challenge for the thesis study. Also big thanks to all my colleagues in Operations who provided valuable feedback in different stages of the study.

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The thesis focuses on developing a scalable maintenance model which is suitable for different size production units whose business focus is also different. The need for the model emerged from a newly established joint venture of the case company where factory maintenance operating practices differ between new partners. Aligning these practices and implementing best fit maintenance procedures would keep up machine efficiency when increasing volumes are expected for the coming years.

The thesis study was conducted according to the design research approach and started with the relevant literature review for best practices on maintenance model building. The current state analysis of the maturity level of maintenance related operations was based on the conceptual framework and was done as thematic internal survey. The current state analysis included also cost/quality structures. The gap analysis was performed on tactical level. The guidelines for the maintenance model were co-created with the case company key individuals based on literature and gap analysis. The proposal for the scalable maintenance model was introduced for validation with different maturity levels within the case organization.

The proposal for the scalable maintenance model consists of the *framework*, *selection criteria*, *site maintenance framework* and *implementation guidelines* including *action planning template*. The common focus areas within the Group together with the factory-specific areas are considered and placed into the framework according to the selection criteria. The outcome of the model, the site maintenance framework is supported with the implementation guidelines and action planning template to enable performance management.

Implementing the common maintenance model is likely raise the level of asset management remarkably. It will prepare production for the upcoming years ensuring the basis for the profitable growth of the case company.




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|---|---|
| Keywords | Maintenance model, Scalability, World Class Maintenance, Asset Management, Best practices. |

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# 1 Introduction

Maintenance operations enable manufacturing companies to create revenue. The ultimate purpose of industrial machines is to process materials into more value-added objects. Production equipment and machines need to be taken care of, otherwise they are not able to full fill the purpose. Modern machinery has developed to the direction that it can also indicate the need of maintenance by themselves but the most of those still need to have repetitive and planned maintenance activities scheduled and executed by competitive personnel.

This study explores factory maintenance in an international multisite manufacturing company. The thesis focuses on ideas for excellent maintenance operations and basics of developing a tactical level scalable maintenance model for executing maintenance within an efficient fashion. With this focus, the Thesis considers also the development of maintenance model for continuous improvement point of view.

Maintenance operations are often considered as a significant cost item in the manufacturing industry. Enhancing maintenance activities should be the top priority of every equipment-heavy organization when optimization in operations are required. The gains of effective maintenance operations come from two directions. On the one hand, allocating money and human resources efficiently and correctly will improve cost benefit ratio. On the other hand, equipment which is operating without unpredictable downtime is able to produce effectively and maintain productivity longer. In most cases also the economic life cycle of equipment can be prolonged and need of costly replacement investments is thus minimized.

## 1.1 Business Context

Kekkilä-BVB, referred to as the case company in this study, is a newly established joint venture between a Finnish supplier of growing media and a Dutch provider of horticulture products. The company provides e.g. garden soils and fertilizers for consumers but also professional growing substrates for greenhouse cultivation in over 70 countries all over the world. The company employs approximately 500 people from several personnel groups in seven countries. The majority owner of Kekkilä-BVB is Vapo Oy which is a 51% state owned company. After the joint venture the production network has 12 sites total which are divided into North and Central operations.

Operating practices in the various functions differ between these two new partners. One of these functions is maintenance operations in factories. Aligning practices and implementing best fit procedures could raise the level of asset management remarkably. It would prepare production for the upcoming years ensuring the basis for the profitable growth of the company.

### 1.2 Business Challenge, Objective and Outcome

The overall maintenance costs of the case company are not above industry average in relation to volumes of produced goods. Still the challenge is that the outcome of maintenance activities is not sufficient to keep up machine efficiency when increasing volumes are expected for the coming years. Also, the 12 factories have very different practices and cost structures in maintenance operations.

Accordingly, *the objective is to develop a scalable maintenance model,* which is suitable for different size production units whose business focus is also different. The outcome of the study is maintenance model.

### 1.3 Thesis Outline

The scope of this thesis relates to providing a tactical level maintenance model. It takes into account best practices among production network and provides guidelines on how to manage operations, instead of details in a one or more specific areas. The thesis focuses on internal operations and management of external services is excluded from the scope.

The study starts with the relevant literature review for maintenance model building best practices. The current state analysis of the level of maintenance related operations and spare part management practices is based on the conceptual framework. The current state analysis includes cost/quality structures.

Gap analysis is performed on tactical level and cost/quality point of view. The guidelines for maintenance model are created based on literature and gap analysis and proposal for the scalable maintenance model is introduced for validation with different maturity levels within the case organization.

The thesis is divided into sections, where section 1 is introduction. Section 2 describes the methods used in the thesis. Section 3 introduces different concepts and best practices from literature. Section 4 continues with the current state analysis, in which findings

of surveys, documents and interviews are analyzed. Section 5 illustrates the creation of maintenance model based on gap analysis of current state and literature best practices. Section 6 describes the validation process of the maintenance model and introduces the final proposal for the maintenance model with the recommendations for further development. The last section summarizes the thesis and the credibility of the thesis is evaluated.

# 2 Method and Material

This section explains the methods and materials used in the thesis. First, the research approach is described. It is followed by the research design and finally the data collection plan with analysis methods used in this study.

## 2.1 Research Approach

There exist different types of methodologies used to conduct study. These research methodologies used are generally classified into two main types which are the fundamental research method and the applied research method. The basic research is mainly performed in universities with the aim to expand the existing knowledge or explain universal principles. It is based on the theoretical analysis (Saunders et al. 2019). In this kind of basic research less attention is given to practical implementations of solving problems at hand. Applied research, on the contrary, is targeting to find a solution or a value to specific issues in industrial and business environments. It is also typical that the problem is meant to be solved within a tight time frame (Kothari, 2007).

Research strategies can be separated into qualitative and quantitative type of methods. The methods utilize different types of data which is the most significant factor how the methods differ from each other. The data is classified as qualitative when it is, for example, gathered from personal interviews and documented in the form of text. Quantitative data is in turn collected, for example, from surveys and questionnaires without close personal contact between a data collector and a respondent and the data is number based. The research can be either purely based on qualitative methods, or based on quantitative methods, or it can also be a combination of both and termed as “blended” or “mixed methodology”. In applied research, the methods are often mixed (Kananen 2017).

In mixed methodology, which is more typical to business studies and organizational researches in applied research, a few main research approaches are used. Alongside the more traditional ones, i.e. case study and action research, also the design research is often applied. The design research, or the applied action research as it also called, considers organizational issues, implementing of changes and working with the improvement of the existing process. “The design research approach produces functional and

practical solutions" (Kananen, 2017). Design research can be conducted in an organization to improve its operations, which can be related to the product, process, services and business situations (Kananen, 2017).

Based on the above discussion on different approach options the Design research was chosen for this study. It is the most suitable for process development where existing operation models are evaluated and re-designed based on best practices. Time available for the development does not allow the action research method which could have otherwise been suitable for this kind of a development. For this study mixed methodology of qualitative and quantitative data collection techniques are conducted to understand the current state of maintenance operations and to develop the process within-depth, personal approach.

## 2.2 Research Design

This sub-section describes the research design and methodology for the study. The study was conducted in five steps with three data collection rounds. Figure 1 presents the research design for the study step by step. In addition to this it shows the input data collections and the outcome of the different stages of the study.

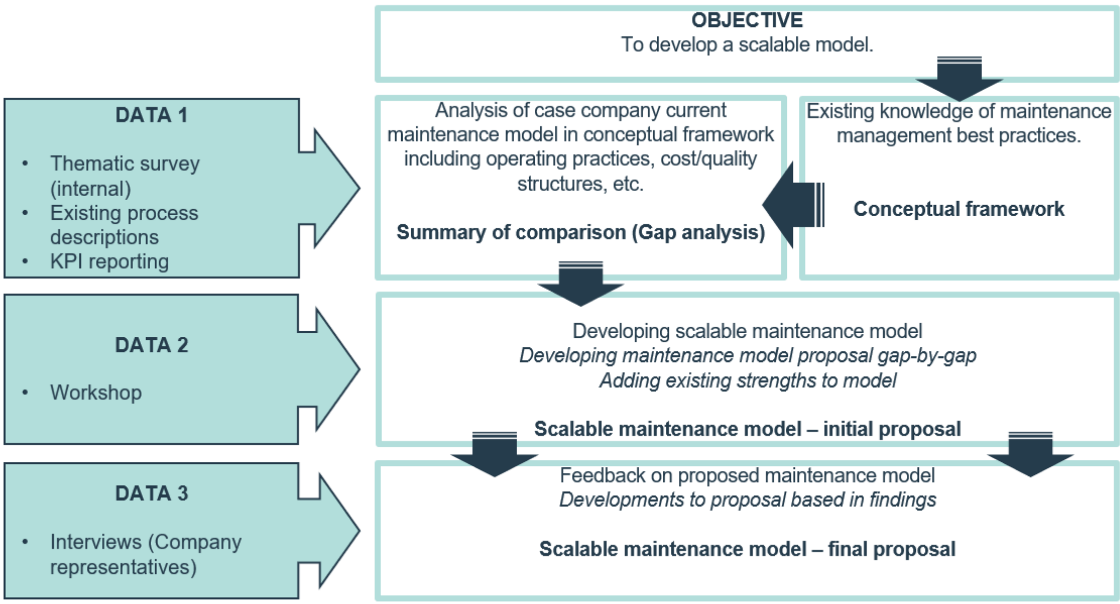


Figure 1. Research design of the study

As shown in Figure 1, the first phase of the research design was identifying the business challenge and objective for the study. The second phase consisted of literature research for identifying the elements of the maintenance management model. It was done according to the different concepts, maintenance model scaling and relevant literature. Based on the research, the outcome of phase 2, a conceptual framework was established as the "ideal process" to serve the basis for developing the model. The conceptual framework was utilized in the third phase which was the current state analysis of the case company existing maintenance model. This phase described the current maintenance models and summed up the strengths and weaknesses of the maintenance models in a context of conceptual framework, focusing on the gaps to be improved later.

The next stage started with a workshop involving relevant stakeholders, where the main outcome from previous stage was used to develop maintenance model. The output of the workshop was then used to finalize an initial proposal for improved maintenance model which was the main outcome of phase 4. For writing the final proposal in phase 5, model was tested accordingly and a management review was arranged to collect feedback for finalizing the proposal. Based on this data input 3, the phase then ended with the final proposal for the improved maintenance model.

## 2.3 Data Collection and Analysis

This study draws from several data sources which were collected in three separate data collection rounds. In each round appropriate data was collected for a certain purpose to be able to focus into the topic on the hand. The data collecting rounds were done according to research design plan. The table 1 below shows the data plan for all three data collection rounds.

Table 1. Details of data collection rounds 1-3

| DATA PLAN | Data Type | Data Source | Schedule & Approach | Recordings | Purpose / Focus |
|---|---|---|---|---|---|
| **Data 1**<br><br>**Current State Analysis** | Internal Documents | • Existing process descriptions<br>• KPI reporting | DEC 2019 collection and review of documents | Transcribed | To gather knowledge of existing procedures and the current state of operating activities |
| | Internal thematic survey based on CFW | • Maintenance technician(s)<br>• Maintenance Engineer(s)<br>• Site Manager(s)<br>• Operations Director(s) | JAN 2020 - Multiple choice questions web survey | Survey results | Operative level, managerial level and directorial level experience |
| **Data 2**<br><br>**Developing scalable maintenan ce model** | Workshop | • Maintenance technician<br>• Maintenance Engineer<br>• 2 Site Managers | MAR 2020 | Written notes | To create the proposal in cooperation with selected individuals |
| **Data 3**<br><br>**Validation** | Piloting the model<br><br>Management review | • 3 Operations Directors | MAR 2020<br><br>Telco | Site-specific maintenance frameworks<br><br>Written notes | To gather feedback for the adjustments of the proposal |

As seen in Table 1, data for this project was collected in three rounds. The first round consisted of two separate data types of which the internal thematic survey was in a more significant role. This type of method was chosen because the team of experts from whom insights were needed, are geographically widespread to four different countries in 12 production sites. The experts are also working in all levels of the organization which would have made the arrangement of traditional one-to-one interviews almost impossible in the given timeframe. The conceptual framework created based on literature view was the basis for the survey and it was targeted to get input from operative, managerial and directorial levels. The questions for the thematic internal survey can be found in Appendix 1.

The second data type used in the first data collection round was the case company existing documentation, shown in Table 2 below.

Table 2. Internal documents used in the current state analysis, Data 1

| | **Name of the document** | **Number of pages/other content** | **Description** |
|---|---|---|---|
| A | Maintenance operations – Eurajoki factory | 3 diagrams | Diagrams for Maintenance Processes |
| B | Kekkilä Group - Maintenance costs report | 6 tables | Financial reporting |

As seen in the Table 2, this study also analyzed several internal documents. The main documents included descriptions of factory maintenance operation procedures and reported maintenance key performance indicators. These reports include indicators of maintenance costs and machinery offline hours, explaining the quality level of the maintenance operations. The collected data were analyzed using content analysis.

In the next round, "Data 2", data was collected to gather suggestions from the case company maintenance teams for developing the proposal. This data included a workshop with selected key individuals from operational and managerial level working in the field of maintenance. The workshop was conducted face-to-face and the workshop content was based on the gap analysis performed with the input from literature review and current state analysis.

The final data for the initial proposal validation was collected when receiving feedback from the case company executives in management review held via Teams, the video conferencing software. The material for review was conducted from piloting the model beforehand.

# 3 Best Practice on Maintenance Operations

This section discusses best practices in maintenance operations. First, the definition of maintenance is discussed, and strategic element of the maintenance activities is aligned. The chapter also describes the most commonly used maintenance models and concepts with an overview of the scalability of the maintenance model. Finally, a conceptual framework for this work is presented with the rationale behind it.

## 3.1 The Definition of Maintenance Operations

Maintenance operations often refer to different techniques and actions intended to maintain in, or restore equipment or machinery to a state in which it can perform its required functions (Kelly, 2006) Many definitions exists in literature and for example Finnish Standard association (SFS-EN 13306) and PSK standard (PSK 6201) have a slightly different approach to maintenance operations. Despite this the content of definitions is broadly in line with British Standards publication (BS 3811:1984) and maintenance operations are considered as written above in the context of this thesis.

According to standards, all means, technical, administrative and managerial actions are included. In a wider perspective maintenance and especially machine maintenance is considered under asset management umbrella which includes also buildings and structures. In this thesis activities related to facilities are excluded. However the asset management best practices are taken into consideration.

To be able to define actual activities performed in maintenance operations the maintenance task types need to be described. These task types are for example preventive maintenance, breakdown maintenance, condition-based maintenance and operator maintenance (SFS-EN 13306). In the picture below task types are illustrated in hierarchical model according to PSK 7501.

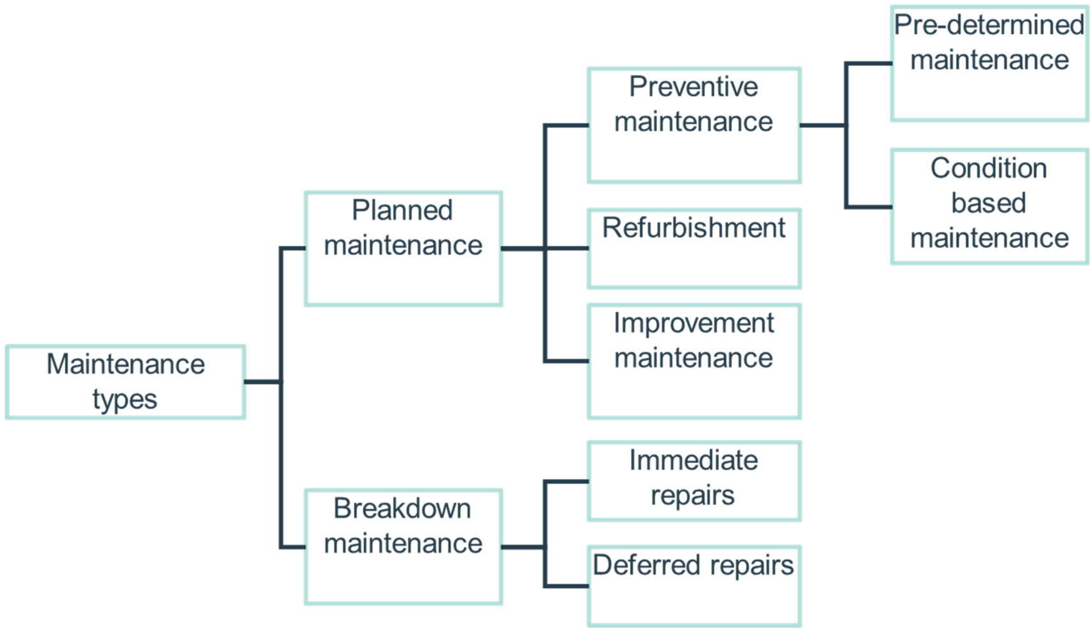


Figure 2. Maintenance types and strategies, adapted from standard PSK 7501

As seen in Figure 2, the standard sets maintenance task types into hierarchy which shows differences between approaches as well as their dependencies. The content of these types will be discussed in more detail in later chapters when describing different models.

## 3.2 Strategic Maintenance Management

This subsection is opening the concept of maintenance from a strategic perspective. On the one hand maintenance operations should be aligned with the company strategy to support the business objectives. On the other hand, any operations need to have strategic objectives to be able to proceed with continuous improvement approach (Pintelon et al. 2006). The next chapters focus on strategic alignment and a company maintenance strategy setting.

A company's production strategy and market requirements set varying targets for production machinery and equipment. The chosen strategy determines the frequency, duration and cost of the maintenance operations. (Kelly, 2006) Traditional manufacturing machinery is maintained to extend the lifecycle and minimize re-investment need of equipment in the long run. This allows higher effort for maintenance, meaning time and personnel. The time spent on maintenance is out of production hours, but when done properly, improves the efficiency of the production machine and thus accelerates the

depreciation value of the machine. If, on the other hand, a company is working on new, emerging technologies, the manufacturing technology will become obsolete faster than the end of the life of the machines. In this case, it does not make sense to “waste” production time on maintenance activities to extend the life cycle, but to operate machines on a continuous basis until they wear out. (Peng, 2012)

A company may have an ambitious growth strategy whereby production machine capacity will be a limiting factor in a few years and new acquisitions will be needed to meet the increased sales. In such cases, the effort in maintenance may not bring the desired benefits. The equipment may also be involved, for example, in the distribution of electricity and energy, whereby its production cannot be stopped without replacement production being arranged. According to Swanson (2001) maintenance strategies can be divided into three different types which all have preferable models that execute strategy accordingly. The three types are as follows: 1. Reactive strategy (Corrective maintenance), 2. Proactive strategy (preventive and predictive maintenance), 3. aggressive strategy (Total Productive Maintenance). In the next subsection the models mentioned above are presented in more detail.

### 3.3 Best Practices on Maintenance Operation Processes

Best maintenance practices have evolved over the decades. From these maintenance approaches, in other words, models, one can distinguish clear development steps that have been evolved by the changing business environment. In this subsection those models and prevailing concepts are reviewed. In the end of this subsection the rationale for selecting key concepts for the case company model are stated.

In pre-maintenance era the equipment was repaired when machines were down. The objective of this phase was to complete repair work in a reasonable amount of time without impacting production significantly and maintenance function did not exist in companies. A unplanned breakdowns however had an effect on production schedules and product quality. This created the need to reduce unscheduled downtime and defects and led to the new phase where maintenance activities were planned and done beforehand. (Peng, 2012)

The beginning of maintenance operations management can be tracked to 1950´s were the focus from corrective actions only was moved to preventive actions. Preventive maintenance (PM) is defined as “performing a series of scheduled or planned tasks that either extend the life of an asset or a system or detect critical wear that causes the asset or system to be about to fail”. PM is still one of the key concepts in maintenance management (Peng, 2012). Although PM was a significant development step, it also has its disadvantages. Preventive maintenance is done on a time basis and checklists are created for the tasks. Spare parts are purchased in advance to allow efficient operations. For PM, the machine must be stopped, and production cannot be made. This lost production time, combined with spare part practices, can make preventative maintenance expensive and inefficient. Daily, weekly and monthly maintenance is often based on recommendations from the equipment supplier and does not consider the actual utilization rate of the machines.

The preventive maintenance phase focused on improving mainly the reliability of the machines. The next step was productive maintenance of which one objective is improving the efficiency of maintenance operations itself. For the efficient maintenance management statistics and metrics such as mean time between failure (MTBF) and mean time to repair (MTTR) were utilized to measure equipment reliability and maintainability. The MTBF indicates the frequency of occurrence of a device or machine failure and the MTTR average time it takes to repair the equipment. The MTBF meter can be used to schedule preventive maintenance programs in more detail. MTTR, on the other hand, is suitable for measuring the capability of a maintenance work and the goodness of a maintenance organization. These two concepts improved efficiency and are nowadays widely used.

### 3.3.1 The “Total Productive Maintenance” Concept

At the turn of the 1970s and 1980s, the Japanese automotive industry introduced several production managements concepts. One was Total Productive Maintenance (TPM), which combined the above mentioned preventive and productive maintenance practices with their total quality control concept (TQM). The TPM model has very aggressive maintenance targets: zero breakdown and zero defects (Peng, 2012). The main contribution of the concept is to involve production operators in equipment maintenance. The

model includes PM metrics, checklists and to-do lists, but some basic work is the responsibility of the operators. In addition, the model requires close collaboration between production and maintenance to coordinate maintenance and production schedules.

### 3.3.2 The Condition-Based Maintenance

The latest development in maintenance is related to increased technology and digitalization. The development of Computerized maintenance management systems (CMMSs), which began in the 1980s, has provided an opportunity to plan and direct PM tasks in the digital platforms. The systems are also often equipped with condition monitoring sensors to predict the time of failure enabling possibility to remove it before the break occurs.(Veldman 2011) This condition-based maintenance (CBM) is one of the key elements in this current phase in maintenance management, called the predictive maintenance (PdM) phase. The predictive maintenance focuses on determining the expected life of the components and replacing and servicing them at the optimal time. Nowadays it is common that equipment has self-monitoring capabilities. The development of CBM technologies in areas such as vibration, noise and optical sensing have helped the implementation of the predictive maintenance concept (Peng, 2012).

### 3.3.3 The “World Class Maintenance” Concept

To overcome the identified challenges in implementing the aggressive holistic TPM concept, several researchers and consultants set out to develop an alternative concept called world-class maintenance (WMS). The importance of maintenance operations to productivity and factory operations was recognized. The additional value in WMS concept comparing TPM is that maintenance operations must be aligned with the company's strategy to ensure equipment availability, market quality requirements, on-time deliveries and competitive cost levels. These objectives are also largely in line with the world class manufacturing concept. (Marcus 2004)

For a company to be able to pursue WMS-level in maintenance operations, a maintenance organization should have a knowledgeable and trained team. They must have CMMS in place in order to get rid of manual work recordings and memorized instructions. In addition, CMMS provides reports to support maintenance development. Operations must be based on a proactive maintenance program that defines the tools to be used and the inspections that are required. Digital analysis equipment used in predictive

maintenance (PdM) should be used to monitor equipment condition so that equipment can be serviced on time. In addition to the above, proper lubricant maintenance, cleanliness of equipment and tools, and leakage control of air and hydraulic systems must be at an excellent level. The maintenance organization must be committed to training and safe working practices (Norman 2001)

In 2009 Kodali, Rajesh, and Anand introduced a proposal for WMS framework.

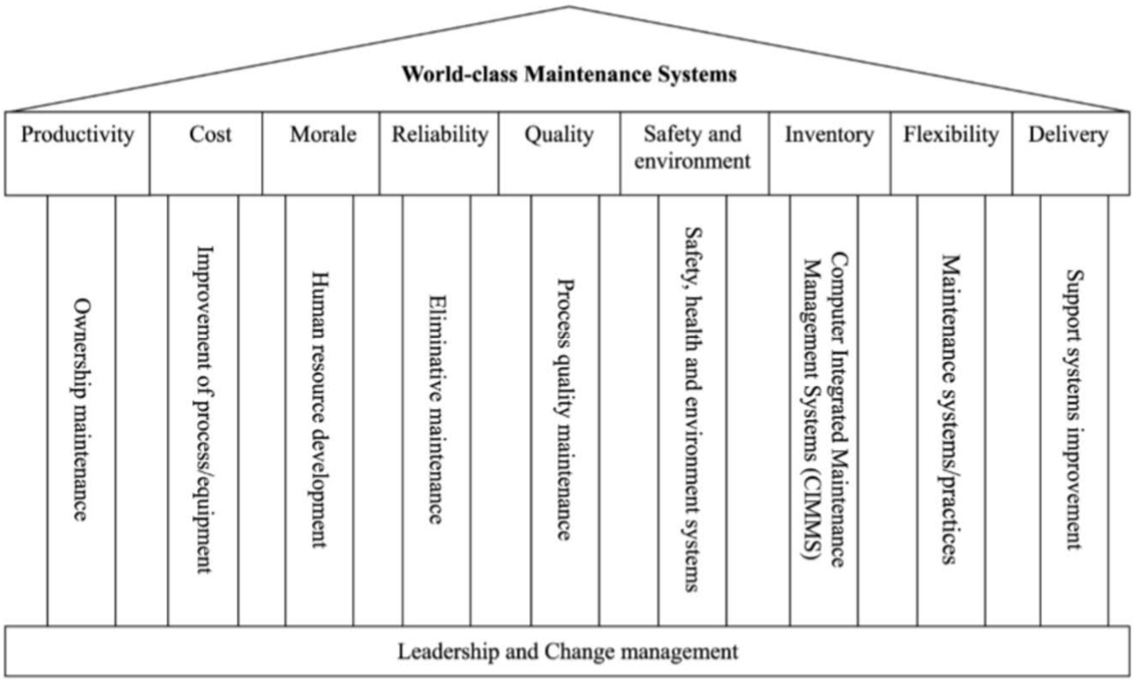


Figure 3. Proposed framework for world-class maintenance systems by Kodali, Rajesh, & Anand, 2009.

As shown in the Figure 3, the WMS framework is closely related to the TPM concept. However, there are differences between them, for example, in the recommendation of using CMMS. TPM does not recognize this element in its framework. Differences between TPM and WMS can also be sought from emphasizing the utilization of the predictive maintenance model. TPM emphasizes its role, but WMS offers the most appropriate models, such as breakdown, scheduled or preventive maintenance, depending on the circumstances, the devices and their criticality (Kodali, Rajesh, & Anand, 2009). The WMS concept can be considered as a collection of best practices from all existing maintenance concepts and models targeting to get the most out of production equipment aligned with the company’s strategy.

### 3.3.4 Reliability Centered Maintenance Approach

When it comes to maintenance models, it is also worth mentioning Reliability Centered Maintenance, which was developed in the 60's for aircraft maintenance. The RCM philosophy differs from other maintenance concepts in that it focuses on system functionality rather than a single device. An important element of the concept is the prioritization of equipment and the criticality analysis that is used to select maintenance activities. For example, machines that are less important to factory operations can be left to run to failure while critical operations and equipment are maintained at all costs (Siddiqui 2009).

RCM assessment classifies all devices in the system according to different steps. In the first step, all devices are identified. After that, all possible failures are listed. In the third stage, the possible causes for the loss of these functionalities are assessed and in the fourth stage the effects of the losses are recorded in four categories: safety, environmental damage, operational, and nonoperational. Finally, plans are put in place to detect and prevent events before they occur. (Peng, 2012).

RCM did not spread outside of the aerospace industry before the 1980s, partly due to the extensive workload required for the analysis. The manufacturing industry's requirements for machine usability and reliability are not in that high level than in aviation. As a result, the workload required for a comprehensive analysis has been difficult to value from the economic payback perspective. As a summary of different maintenance models, the following table of maintenance management phases is presented.

Table 1. Maintenance management historical phases adapted from Peng, 2012

| | Period | Characteristics | Objectives | Concepts Developed |
|---|---|---|---|---|
| **Phase 1** Breakdown management | Pre-1950 | Repair only when machines were down | Repair equipment failures in reasonable time | "If ain´t broke, don´t fix it." |
| **Phase 2** Preventive maintenance | 1950s | Establish maintenance functions Time-based maintenance | Extend equipment life Reduce unscheduled downtime and defects | Preventive maintenance Productive maintenance Maintainability improvement |
| **Phase 3** Productive maintenance | 1960s | Reliability focus Maintainability focus Cost conscious | Reduce unscheduled downtime and defects while increasing maintenance efficiency | Reliability engineering Maintainability engineering Engineering economy Reliability-centered maintenance (RCM) |
| **Phase 4** Total productive maintenance (TPM) | 1970s | Preventive maintenance plus TQC and total employee involvement | Zero breakdownd and zero defects | Systems engineering Maintenance prevention Just in time (JIT) TQC and TQM |
| **Phase 5** TPM with predictive maintenance | 1980s-1990s | TPM practices Condition-based maintenance Application of CMMS | Zero breakdownd and zero defects Optimization of availability | Computerized maintenance management Artificial intelligence and expert systems |

Table 1 presents five phases of the historical development of the maintenance management. The phases are named on column on left, followed by indication of prevailing era on second column. The characteristics typical for phase are described on third column. Each phase has clear objectives which are stated in column four followed by column 5 on right side to explain the concepts developed during era.

The historical development of models is giving one angle how to scale a company maintenance model to different maturity levels of operations. This approach is more discussed in the next subsection.

## 3.4 Scaling the Maintenance Operations

A scalability must be added to the maintenance model in order to adapt it to the varying operating environments at production sites. The Asset Healthcare Triangle Model by Peterson from 2006 introduces asset management operational excellence pyramid which sets applicable elements of different maintenance concepts in a hierarchical order. The pyramid emphasizes a logical approach to best practices through development stages towards operational excellence in maintenance operations. (Lifetime Reliability Solutions 2020). Petersons referred triangle model is one element in strategic asset management method (SAM) which provides a roadmap for developing site operations from the perspective of production, assets and logistics.

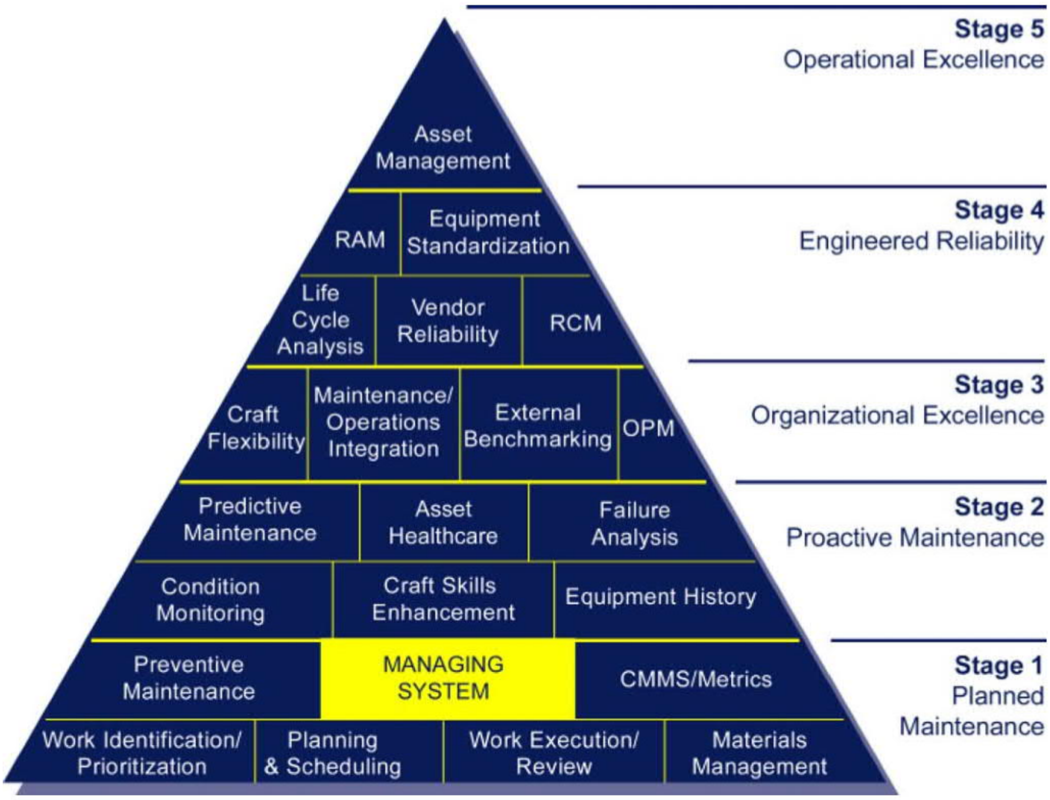


Image 1. Asset Healthcare Triangle Model (Peterson 2006)

Image 1 illustrates five stages which all contain elements from maintenance models to be performed accordingly to reach the next stage. The stages can be defined as indicators of the maturity level of maintenance operations. The SAM method provides also a detailed assessment guide for each activity and level.

## 3.5 Conceptual Framework of This Thesis

This sub-section presents the conceptual framework of the thesis. The framework has a strategic alignment as a starting point which defines applicable maintenance models. Based on chosen maintenance models the key concepts can be identified and with scalability element the proposal for maintenance model can be established. Figure 4 on the next page presents the conceptual framework. In addition to this it shows the logical progress of creating the framework.

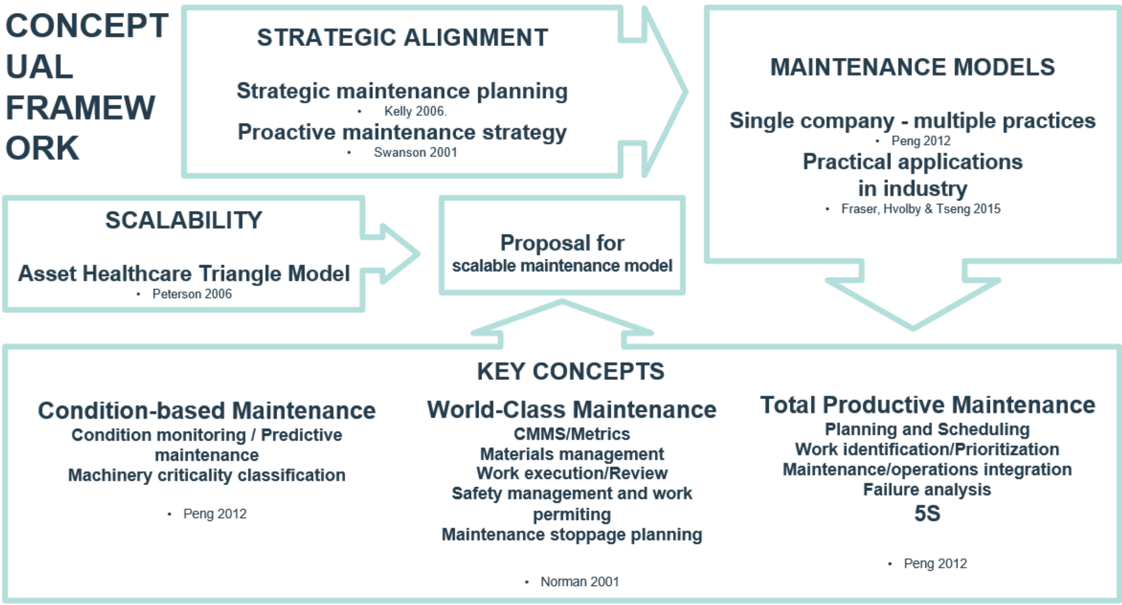


Figure 4. Conceptual framework of thesis

The first element of the conceptual framework is the strategic alignment of maintenance model. The growth strategy of a company and the position of the manufactured products in the value chain, will influence the maintenance strategy to be chosen. A company with an ambitious sales growth plan is forced to renew machinery to keep up with the increased demand. In this case, the production machines must be replaced before their technical lifetime is reached and excessive maintenance is not needed. In some cases, the low value-added products will not allow a company to invest in high-end machinery to be able to keep costs of goods sold in a reasonable level. This situation determines that maintaining the company's production equipment is more preferable than replacing it with a fast cycle or let them wear out. This type of conclusions sets the proactive strategy (preventive and predictive maintenance) as the basis for the maintenance strategy of the company. Sometimes products to be manufactured are for a niche sector and the production machinery is very specialized for those. This can restrict fast phase technological innovations in the industry and keep old technology competitive for decades. Again, preventive maintenance is the most beneficial approach.

The second element in this thesis conceptual framework is the key concepts to be used. The key concepts mean the different maintenance models described as best practices. Even though different maintenance models were created decades ago, they are still widely in use. A study of the published literature to identify empirical evidence by Fraser

et al. from 2015 deals with the occurrence of different maintenance models in the academic literature. The study focuses on the number of practical applications in industry. Of the 42 models listed in the academic literature only five were found to be listed more than once: TPM, RCM, CBM, TQMain, and PM. These five models were repeated ten times, which means 32 different models.

The maintenance model of a company should be based on practical elements that have been verified by as many companies as possible in the real environment. The study reveals three of the most used models quantitatively TPM, CBM and RCM. RCM however as described above tends to be more suitable for machines and equipment that require extremely high availability and safety and is therefore not the optimal approach for all companies. Depending on the industry and the requirements of production, even a single company can have elements of different models and concepts at their disposal. This type of multiple practices will be the approach for this study. The focus is on world-class maintenance concept while being the enhanced version of TPM including elements also from CBM.

The third element of conceptual framework is scalability of maintenance model. By placing the functional elements of the different maintenance models into triangle model pyramid by Peterson, the elements can have a vertical dimension that can be used to scale the model for different maturity levels of factories and operations. This vertical dimension will conclude the framework of this thesis by providing practical application for scaling the maintenance model with practical implementations of the best practices. These key concepts will then be the basis for current state and gap analysis of the maintenance model as well as model development.

# 4 Current State Analysis

This section discusses the current state of the maintenance operations in the case company. The current state is explored based on best practices across different industries.

## 4.1 Overview of the Current State Analysis Stage

An internal survey was chosen as the main tool for studying the current state. The reason for the selection is the wide geographic network of factories, covering 12 sites around the Baltic Sea and the Netherlands. It would have been too challenging to carry out an interview study with the numerous contact persons of all sites within the given timeframe. This type of approach allowed efficient time usage and good coverage. The survey was supported by the evaluation of the company's financial performance indicators and with the review of the existing maintenance process descriptions.

First, the key concepts from literature were transformed to a set of questions that could be presented in the survey. In addition to key concepts, the maintenance organization was mapped with the questions asked. An invitation to the survey was sent to each site representative to be shared for all key individuals in the maintenance operations. The responses received were categorized and recorded to establish a maturity level indicator.

Second, the cost structure of maintenance was examined through financial reports. The reported maintenance costs were allocated in relation to the factory output volumes to be able to benchmark cost efficiency of the maintenance operations between the sites.

Third, the existing maintenance process descriptions were reviewed. The documentation was stored into the case company´s management system and included the following basic processes: corrective maintenance, preventive maintenance, maintenance planning and spare parts handling. The descriptions existed only for the Finnish factories' operations and only in Finnish. The next sub-sections discuss these three phases in more detail.

## 4.2 Maturity Level Analysis

As mentioned above, the thematic survey was selected as the main tool to map the maturity level of the current maintenance operations. In table 2 the chosen key concepts are shown in relation to questions to be implemented into the survey. This transformation included the translations of concepts according to the processes used by the case company.

Table 2. Key concept relation according to question set

| **Stage**<br>*Scalable level* | **Element**<br>*Asset Healthcare Triangle Model* | **Application**<br>*Adapted from key concepts for the case company* | **Referenced model** |
|---|---|---|---|
| Planned maintenance | Planning and Scheduling | Daily plan and schedule | Preventive Maintenance |
| | Work identification/Prioritization | Maintenance work classifications | Total Productive Maintenance |
| | Materials management | Spareparts and warehouse management | World-Class Maintenance |
| | Work execution/Review | Maintenance KPI´s and cost follow-up | World-Class Maintenance |
| | Preventive maintenance | Calendar based preventive maintenance | Preventive Maintenance |
| | CMMS/Metrics | Maintenance management system | World-Class Maintenance |
| Proactive maintenance | Condition monitoring / Predictive maintenance | RTM (Running Time Maintenance) | Condition-based Maintenance |
| Organizational Excellence | Maintenance/operations integration | Operator maintenance | Total Productive Maintenance |
| Engineered reliability | Failure analysis | Root cause analysis | Total Productive Maintenance |
| | - | 5S | Total Productive Maintenance |
| | RCM, Equipment history | Machinery criticality classification | Reliability Centered Maintenance |
| Operational Excellence | Vendor reliability | Contractors and service management | Total Productive Maintenance |
| | - | Safety management and work permiting | World-Class Maintenance |
| | - | Maintenance stoppage planning | World-Class Maintenance |

In table 2 above the two central columns of the table contain the key concepts selected from the maintenance models in comparison to the elements of the triangle model pyramid by Peterson discussed in section 3. The column on the right shows the maintenance model from which the practical application is derived. Almost perfect compatibility indicates that the elements selected are widely representative of best practices available. However, it is not possible to find full compatibility because the elements are selected from different models. The left column indicates the different degrees of maturity and has been used to visualize and set the order of the questions.

### 4.2.1 Implementation of the Survey

The selected tool to execute the survey was the case company´s existing survey tool, “get feedback” (https://www.getfeedback.com/) It is mainly used for customer surveys but also utilized for different types of internal surveys in the case company. The tool has

a simple user interface and it provides a standalone web link to the survey which can be shared by email.

Before the questions could be put into the tool, it was necessary to build a query logic that guides the respondent. Microsoft's Excel software was used for this purpose. The order of the successive and alternative questions and the progress of the query are illustrated as an example in Figure 5. The full step-by-step process of the questionnaire can be found in appendix 2.

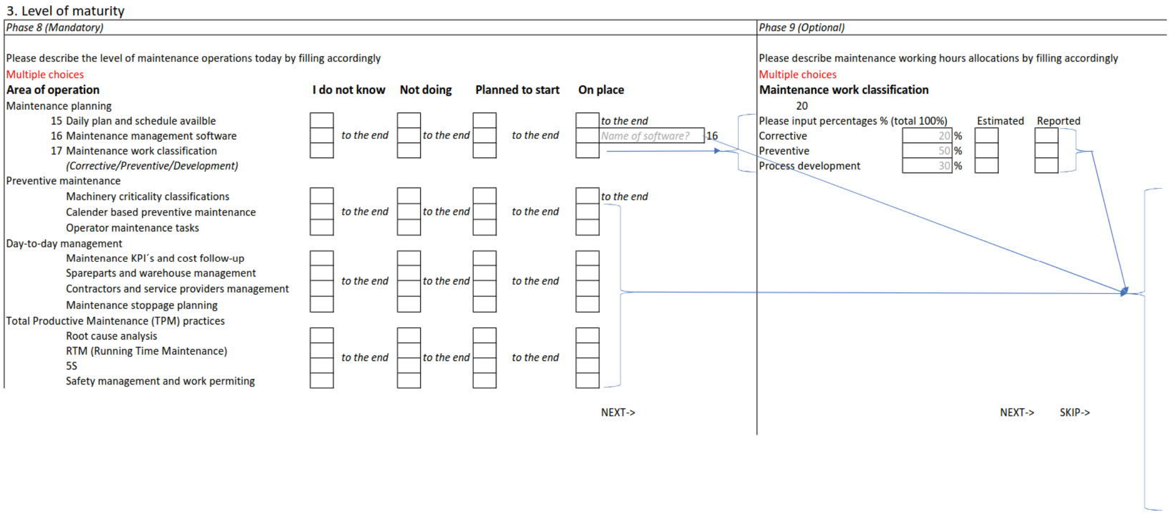


Figure 5. Example of questionnaire step-by-step process

As seen in Figure 5, the questions were referring to the best practice elements and the respondent had four different answer alternatives to the basic questions: ”I do not know”, “Not Doing”, “Planned to start” and “On place”. With these options also the willingness and ignorance on the subject could be revealed in addition to the basic yes or no questions.

In the survey tool the questions were placed according to a step-by-step process and illustrated in a triangle pyramid model with the case company brand colors as seen in image 2.


Image 2. Get feedback single question illustration

Image 2 shows how the respondent was able to see the stage of the question in context with the highlighted area of operation. This color coding was also easing the follow up of the progress of the survey.

Some of the questions included additional options to refine the overall picture. However, if the respondent stated that this sub-domain was not applicable to operations, the query automatically skipped over the refinement questions. Below are two examples of these clarifying questions: one with the free option and the other with the pre-selected options.

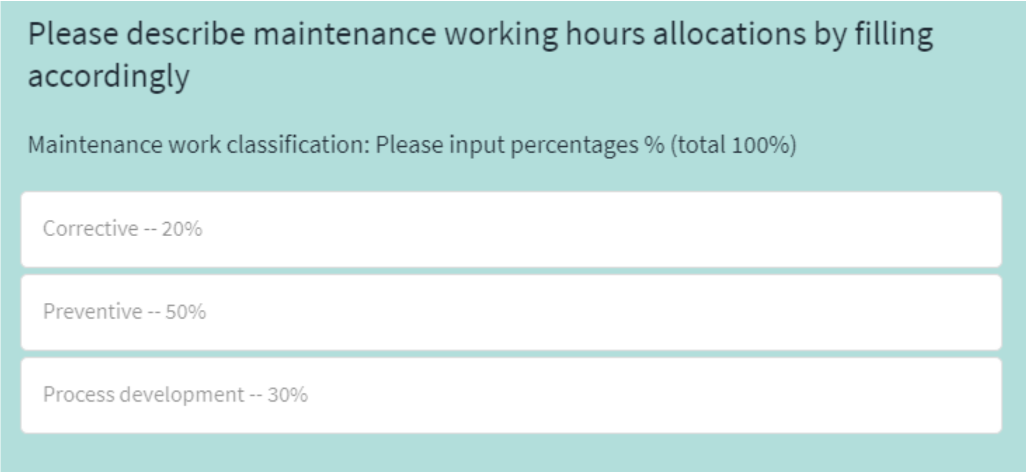


Image 3. Get feedback additional question with free text fields

Image 3 shows how the respondents were asked to fill in percentages of the amount of total working hours regarding certain maintenance operations.

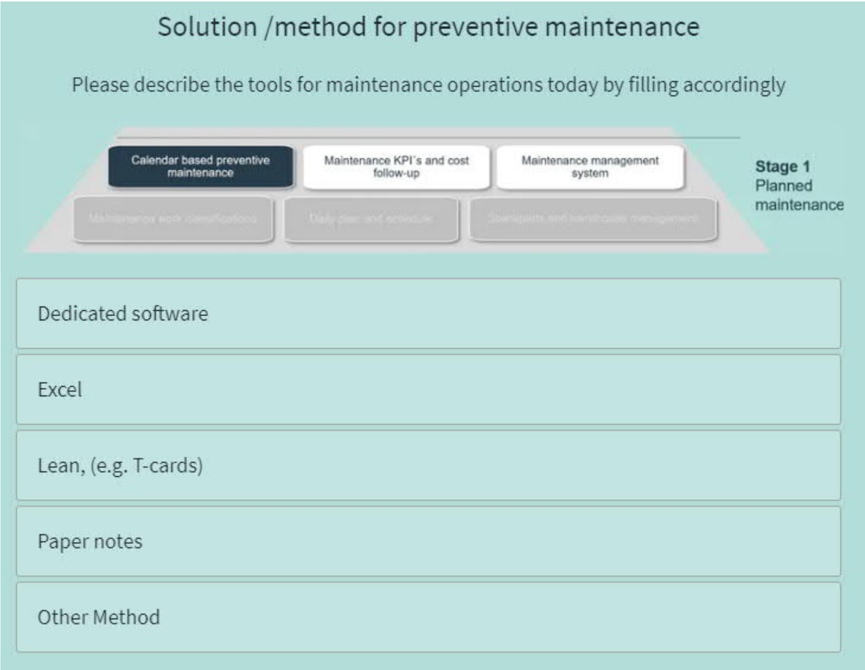


Image 4. Get feedback additional question with pre-selected fields

Image 4 illustrates how the tools used for calendar based preventive maintenance were asked in case of pre-selected options.

The Get feedback survey tool provides questionnaire results in Microsoft excel format to elaborate. Thirteen of the fourteen sites invited to the survey received a response. The rows represent these thirteen sites. The received results were categorized, and the percentages were statistically recorded in Excel with the following logic shown in the table below. All results can be found in Appendix 3.

Table 3. Example of survey results categorization and the percentage of different responses

| 18. Area of operation: Maintenance planning - Maintenance work classifications (Corrective/Preventive/Process development) | 20. Area of operation: Preventive maintenance - Machinery criticality analysis | 21. Area of operation: Preventive maintenance - Calendar based preventive maintenance |
|---|---|---|
| I do not know | On place | Planned to start |
| On place | On place | On place |
| Not doing | Not doing | On place |
| Planned to start | Planned to start | Planned to start |
| Planned to start | Planned to start | On place |
| On place | On place | On place |
| Planned to start | Planned to start | On place |
| On place | Not doing | On place |
| On place | Planned to start | On place |
| Not doing | Not doing | On place |
| I do not know | Planned to start | Planned to start |
| Not doing | Not doing | On place |
| Not doing | Not doing | Not doing |

| | | | | | |
|---|---|---|---|---|---|
| On Place | 31 % | On Place | 23 % | On Place | 69 % |
| Planned to start | 23 % | Planned to start | 38 % | Planned to start | 23 % |
| Not doing | 31 % | Not doing | 38 % | Not doing | 8 % |
| I do not know | 15 % | | | | |

As seen in table 3 the percentages of the different answers for each question area are calculated to show the current state of maintenance operations at the specific site. The colors are showing individual answer status with traffic light illustration. The results and conclusions are discussed in more detailed in sub-section 4.5.

### 4.2.2 Maintenance Organization

The thematic survey included mapping of the existing maintenance organization. The respondents were asked about their own position in the organization as well as other roles and responsibilities on site level. In table 4 below the maintenance organization roles and number of the personnel are shown.

Table 4. Composition of maintenance organization

| Site | Number of Maintenance manager in this site | Number of Maintenance engineer in this site | Number of Maintenance technician in this site | Number of Maintenance Service provider in this site | Number of Other, what in this site |
|---|---|---|---|---|---|
| De Lier | | 1 | 1 | | |
| Drachten | 1 | | 1 | | |
| Eurajoki Fertilizer | | 0,5 | 2 | 1 | |
| Eurajoki Substrate | | 0,5 | 2 | 1 | |
| Grubbenvorst | 1 | 1 | 5 | 0 | |
| Hardenberg | | | 1 | | |
| Joutseno Biorefining | | | | 4 | 1 |
| Mosås | 0,5 | | 1 | 5 | |
| Niibi | 1 | | 0 | 5 | |
| Nurmijärvi Biorefining | 0 | | 0 | 0 | 1 |
| Parkano | | | 2 | 1 | |
| Perstorp | | | | | 1 |
| Wijchen | | | 0,25 | | |
| Total | **3,5** | **3** | **15,25** | **17** | **3** |

As seen in table 4 the organization is very flat. The sites have coordinating roles such as the maintenance focused manager or engineer. Still some of the sites are very self-directed with the help of the site manager. In addition, the role of operators is emphasized in sites where a specialized technician does not exist. At the group level, the total number of persons is almost the same for both in-house maintenance and external service providers. This indicates that there are clearly two operating models, namely outsourced maintenance services or use of own maintenance personnel. The workload is the same, but resource utilization is different. The decimals indicate that some sites use partial shared resources with production or another site. The designated operators do both maintenance work and operate production machines.

## 4.3 Cost Structure Analysis

As the case company is the a newly established joint venture, its financial reporting is still split in two different practices. In the north operations, maintenance costs have been monitored at the account level. The accounts followed have included maintenance spare parts and fittings, maintenance personnel salaries, and the purchased external services. The central operations, mainly based in the Netherlands, have instead tracked machine and equipment costs without an itemized breakdown. For this reason, no consistent re-

ports are available. However, on a rough level comparable cost analysis can be established. Even though cost allocation is done differently, volumes produced by sites are the common denominator. By allocating all site maintenance costs together and dividing them by the volumes produced, a metric is provided that reflects the efficiency of the maintenance.

The maintenance cost of the North operations is reported on a monthly basis. Thus, the company's monthly financial reports were easily summarized. The maintenance costs allocated to the various accounts were summed up at the factory level. Monthly reporting also includes production reports from which it was possible to collect figures for the produced volumes. As volumes indicator, the case company uses the substrate cubic's. The production reporting of the central operations is monthly, but maintenance costs are monitored on an annual basis. This meant that several separate reports had to be combined to form the metric and that the information was not up to date. To be able to compare data, the North operations costs were selected from the same months than Central operations. Below in table 4 the results from the cost analysis are shown site by site.

Table 5. Maintenance cost per produced volumes site comparison

| Site | € / EN m3 |
|---|---|
| Bredaryd | 0,42 |
| De Lier | 0,70 |
| Drachten | 0,65 |
| Eurajoki substrate | 1,09 |
| Grubbenworst | 0,95 |
| Hardenberg | 1,05 |
| Haukineva | 1,15 |
| Mosås | 0,46 |
| Niibi | 0,74 |
| Parkano | 0,72 |
| Perstorp | 1,95 |
| Wijchen | 0,42 |

As seen in table 5 the variation between sites is quite big. The difference between the most efficient and most expensive is more than double. In addition, the produced volumes affect the metric heavily. The biorefining sites are excluded from both the measure

and the table because the refining of the compost materials cannot be completely equated with substrate production. In addition, the cost structure of one North and Central joint factory has been included as an internal benchmark.

### 4.4 Operating Procedure Analysis

This subsection describes the existing tools and practices of executing preventive maintenance tasks in the form of the process flow chart. These process descriptions were available only for Finnish sites, which only covers three out of six North operations area sites.

Currently the main process for executing preventive maintenance activities is described below. It presents the main steps of the process in execution order involving operative roles. It also shows the connections to the system tools which are supporting the activities in certain process steps.

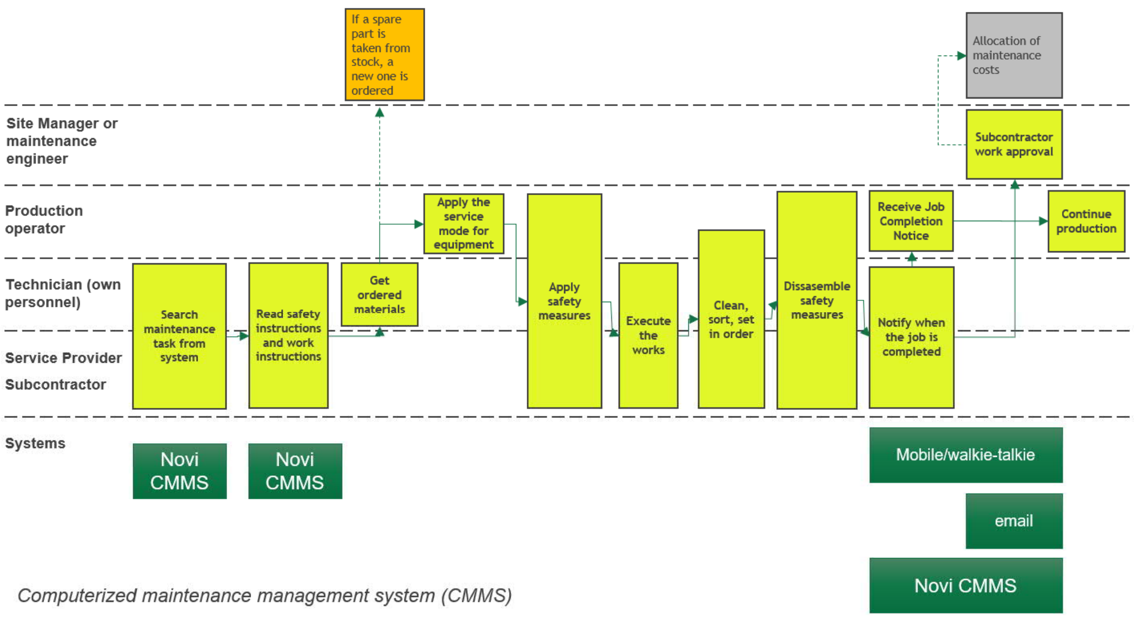


Figure 6. Process flow chart of executing preventive maintenance tasks.

As illustrated in Figure 6 the starting point of the work process is the maintenance task search from CMMS. The Novi system, provided by company named Arrow, is used in the production site for running the maintenance program and scheduling daily activities of the maintenance operations.

The systems provide work and safety instructions including a work permitting functionality. The work permitting is used for wider planned maintenance works and special tasks, which are for example hot work and lifting works. After the instructions have been read, the parts for the tasks are fetched from the warehouse. If the shelf location remains empty, a new part is ordered.

Before the actual work is started the equipment is applied to the service mode by an operator and safety measures are put into the place together with the technician and the operator to secure the working environment. When the work is done, the environment is cleaned, and the safety measures are disassembled. The operator is notified by the technician about the completion of the work and production can be continued. Acknowledgement is done with a mobile phone or with the walkie-talkie. In case of a service provider, the work is approved by the maintenance engineer and costs are allocated for the right items.

## 4.5 Key Findings from the Current State Analysis (Data Collection 1)

This sub-section provides an overview of the current status of the maintenance operations in the case company. It summarizes the key findings from the previous chapters and presents conclusions from the CSA.

The maturity level of the sites is very fragmented. A small number of factories master the basic maintenance operations and have even set up clear processes to implement them. In these sites the maintenance organization is in place and supports the operations. However, most factories use single elements, but the big picture may not be clear. There are challenges at the basic level operations and implementing maintenance practices is not done systematically. At some factories, maintenance does not yet play any role and no effort has been made to develop it. This fragmentation poses challenges for the development of a common model and makes the scaling possibility of the model a very important element. In the following subsections this is discussed in more detail topic by topic.

### 4.5.1 Maturity Level

To illustrate the maturity level of the current state, all question topics are classified and listed site by site. In table 6 below the strengths and weaknesses of the existing maintenance operations are shown. The group level approach is shown in table 7 later in this subsection.

Table 6. Strengths and weaknesses of existing maintenance operations site-by-site

| Site | Strenghts | Weaknesses | |
|---|---|---|---|
| | On place | Planned to start | Not Doing/Not knowing |
| De Lier | Calendar based preventive maintenance; RTM (Running Time Maintenance); Maintenance management system | Safety managementand work permiting; Spareparts and warehouse management; Daily plan and schedule | Root cause analysis; Maintenance KPI's and cost follow-up; 5S; Machinery criticality classification; Operator maintenance |
| Drachten | 5S; Maintenance stoppage planning; Safety management and work permiting; Daily plan and schedule | Maintenance KPI's and cost follow-up; Calendar based preventive maintenance; Machinery criticality classification; Maintenance management system | Maintenance work classifications; RTM (Running Time Maintenance) |
| Eurajoki Fertilizer | 5S; Maintenance stoppage planning; Maintenance management system; Safety management and work permiting; Daily plan and schedule | Maintenance work classifications; Operator maintenance; Calendar based preventive maintenance; Maintenance KPI's and cost follow-up; RTM (Running Time Maintenance); Spareparts and warehouse management | Root cause analysis |
| Eurajoki Substrate | 5S; Calendar based preventive maintenance; Maintenance stoppage planning; Maintenance management system; Maintenance KPI's and cost follow-up; Safety management and work permiting; Daily plan and schedule | Maintenance work classifications; Operator maintenance; RTM (Running Time Maintenance); Spareparts and warehouse management | Root cause analysis |
| Grubbenvorst | 5S; Maintenance KPI's and cost follow-up; RTM (Running Time Maintenance); Safety management and work permiting; Daily plan and schedule | Root cause analysis; Maintenance management system; Spareparts and warehouse management; Maintenance stoppage planning; Machinery criticality classification | |
| Hardenberg | Maintenance KPI's and cost follow-up; Operator maintenance; Calendar based preventive maintenance | | 5S; Maintenance stoppage planning; Maintenance management system; Root cause analysis; Safety management and work permiting; Daily plan and schedule |
| Mosås | Maintenance KPI's and cost follow-up; Maintenance management system; 5S; Safety management and work permiting; Maintenance stoppage planning | Spareparts and warehouse management; RTM (Running Time Maintenance); Root cause analysis | Machinery criticality classification; Maintenance work classifications |
| Niibi | 5S; Maintenance stoppage planning; Maintenance management system; Root cause analysis; Maintenance KPI's and cost follow-up; Safety management and work permiting; Machinery criticality classification | Maintenance work classifications; Spareparts and warehouse management | 5S |
| Parkano | 5S; Maintenance stoppage planning; Maintenance management system; Maintenance KPI's and cost follow-up; Safety management and work permiting; Machinery criticality classification | Operator maintenance; Calendar based preventive maintenance; Daily plan and schedule | Contractors and service providers management; Root cause analysis; Maintenance management |
| Perstorp | 5S; Maintenance stoppage planning; Maintenance management system; Root cause analysis; Maintenance KPI's and cost follow-up; Safety management and work permiting | Spareparts and warehouse management; RTM (Running Time Maintenance) | Machinery criticality classification; Maintenance work classifications |
| Wijchen | | Daily plan and schedule | Maintenance KPI's and cost follow-up; Operator maintenance; 5S; Maintenance stoppage planning; Maintenance management system; Root cause analysis; Safety management and work permiting; Calendar based preventive maintenance |

As shown in table 6, many of the elements are already utilized in the sites. On the left is a list of survey respondent sites. The biorefining facilities are excluded for the reasons mentioned above. For each site, the elements are divided into three categories: *On place, Planning to start* and *Not doing*, which also includes elements classified as unknown in the answers. In the *On place* category, the elements are classified as strengths and the *planning to start* and *not doing* elements are defined as weaknesses. These weaknesses refer to the flaws in the gap analysis of the operational model.

The elements change from one category to another at almost every factory. Certain geographical similarities can be seen. For example, in the North area, CMMS is heavily involved in maintenance operations, while in Central operations, RTM is applied at all major factories. These elements are the opposite of strengths and weaknesses when looking at these factories crosswise.

Another thing to note when looking at the factories geographically is that there are almost always more elements in the *On place* category in the North. The Central, on the other hand, has many more elements in the *Not doing* category. It can be said that the operating models are slightly polarized. This is not a big surprise, as it has only recently merged previously independent actors. The focus points for maintenance management have been different. Table 7 below present the group level objectives chosen from site specific elements.

Table 7. Strengths and weaknesses of existing maintenance operations in group level

| Strenghts | Weaknesses |
|---|---|
| 5S | Spareparts and warehouse management |
| Safety management and work permiting | RTM (Running Time Maintenance) |
| Maintenance stoppage planning | Machinery criticality classification |
| Contractor and service provides management | Root cause analysis |
| Maintenance KPI´s and cost follow-up | Maintenance work classifications |
| Calendar based preventive maintenance | Predictive maintenance |
| Operator maintenance | EAM (Enterprise Asset Management) |
| Daily plan and schedule | System Integrations |
| Maintenance management system | |

In table 7 the weaknesses represent the top 4 elements that factories are not doing in the group level. The polarization causes that a number of sites not doing for instance RTM will emphasize results of that particular element. The gray elements in the table are the continuous improvement level activities, where no replies were received from the sites participating in the survey. The only exception was a few system integrations made by the two factories. However, it can be said that the level of doing continuous improvement specified elements is not on place and they are not included in the maintenance model development from now on.

### 4.5.2 Cost Structures

The maintenance cost structures do not provide accurate enough information to draw conclusions. The cost allocation and organizational differences create too much uncertainty. Still, this one-time review provides a rough comparison and an indication for possible future developments as the financial reporting and cost recording converges in the future. However, the cost structures are not included in the maintenance model development from now on.

### 4.5.3 Operating Procedures and Organization

The Eurajoki production site in Finland in the North operating area has described some of the maintenance operating procedures in quite a detailed level. These process descriptions provide good working instructions for the local organization. However, the process is specific to the Eurajoki operating environment and organization and thus cannot serve as a basis for the entire maintenance model for the case company. It can only be said that similar descriptions should be created for each site for the future.

Organizations with their specific roles are adapted to each site. There are two different approaches for resourcing, namely own personnel versus outsourced services. In table 8 below the number of maintenance personnel were compared to maintenance costs.

Table 8. Number of maintenance personnel compared to maintenance cost measure

| Site | Total number of maintenance resources used | Costs €/m3 | Costs €/m3/persons |
|---|---|---|---|
| De Lier | 2 | 0,7 | 0,35 |
| Drachten | 2 | 0,65 | 0,33 |
| Eurajoki Fertilizer | 3 | | |
| Eurajoki Substrate | 3 | 1,09 | 0,36 |
| Grubbenvorst | 7 | 0,95 | 0,14 |
| Hardenberg | 1 | 1,05 | 1,05 |
| Joutseno Biorefining | 5 | | |
| Mosås | 6,5 | 0,46 | 0,07 |
| Niibi | 6 | 0,74 | 0,12 |
| Nurmijärvi Biorefining | 1 | | |
| Parkano | 3 | 0,72 | 0,24 |
| Perstorp | 1 | 1,95 | 1,95 |
| Wijchen | 0,25 | 0,42 | 1,68 |
| Total | | | |

As shown in table 8 there cannot be indicated any major differences between sites using external or internal staffing. The best performing sites Grubbenvorst and Niibi have opposite approaches: Grubbenvorst with own personnel and Niibi with external service providers. The variation between the sites is more related to the product mix of the site and probably the age of machinery.

As stated above, the lowest common denominator for developing a common maintenance model for the case company will be the utilization of strengths and weaknesses from the maturity level analysis. The next chapter discusses the development of the proposal draft.

# 5 Building Proposal on Scalable Maintenance Model for the Case Company

This section merges the results of the current state analysis and the conceptual framework towards the building of the proposal draft using Data 2.

## 5.1 Overview of the Proposal Building Stage

The objective of this thesis is to develop scalable maintenance model for the case company. The model has been developed based on best practices taken from literature and combined to the knowledge gained from the current state analysis. The fulfillment of the thesis objective requires development of the scalable maintenance model. The main aim is to align practices and implement best fit procedures from 12 factories with very different procedures and cost structures in maintenance operations. The common maintenance model would raise the level of asset management remarkably. It would prepare production for the upcoming years ensuring the basis for the profitable growth of the case company. Currently the outcome of maintenance activities is not sufficient to keep up machine efficiency when increasing volumes are expected for the coming years.

As discussed in the current state analysis, the maintenance practices of the case company are not consistent between factories, neither fully in line with best practices taken from literature. For this reason, it is necessary to build a common frame of reference from which the focus areas for maintenance operations are selected, considering the site-specific strengths and weaknesses.

For the proposal building, specialists within maintenance roles were selected for the workshop. The workshop team included also one site manager and operations manager who has two sites in his area of responsibility. In total, four persons participated in the workshop.

The workshop began by reviewing the thematic survey group level results. After that, the construction of the framework started. The team was assisted by the best elements of the literature and the asset health care triangle, where the maturity levels of the maintenance activities were visible. The weaknesses and strengths of the current state analysis were not considered at this stage because the intension was to build a generic model that scales as needed.

The second part of the workshop consisted of defining focus areas. The results of the current state analysis were implanted in the previously built framework and the selection criteria were discussed in the team. In the final step, practical implementation guidelines for focus areas were discussed. The inclusion of this final step into the model is one of the most important aspects when evaluating the performance of the model. The proposal draft of the model has been designed based on specialists' expectations, best practices from literature and results from current state analysis. The proposal draft consists of the *framework*, *selection criteria, site maintenance framework* and *implementation guidelines.* As an orientation to the topic, the relation between each part of the model is presented in figure 7 below. Each part is discussed in more detail in the following sub-sections.

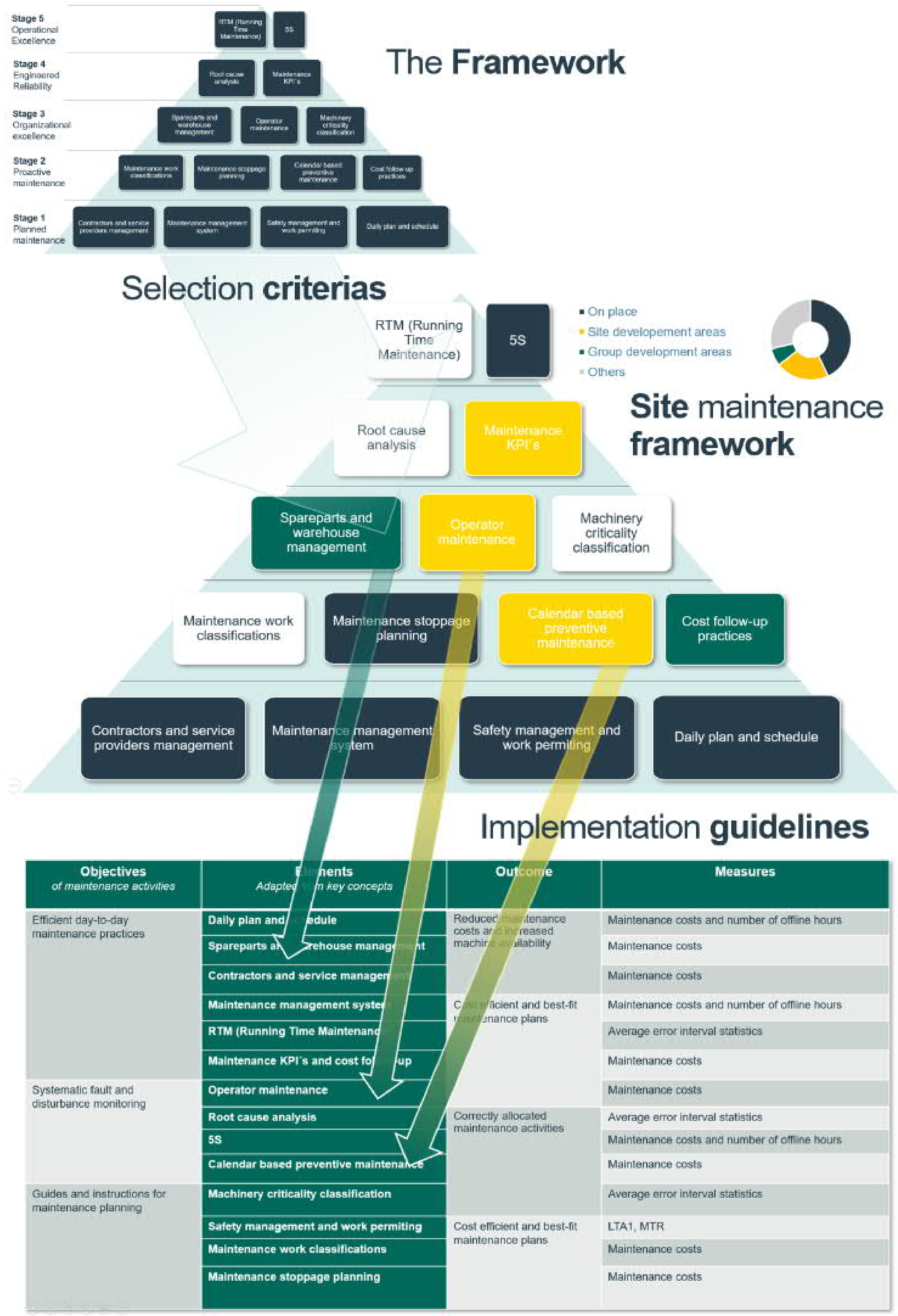


Figure 7. Illustration of the relation between each part of the model

As shown in figure 7 the maintenance model proposal draft is based on the *framework* built from best practice elements found from literature. The elements selected in the frame represent the most appropriate areas of activity selected by the case company representatives. They fall into five different stages according to the need of effort and competence from maintenance organizations. The stages also reflects the level of maturity in the case company's maintenance operations.

The second step in the model is *selection criteria* for focus areas. The elements already in use are marked "on place" and are blue in the figure. The development areas are selected from elements common to the Group as well as from site-specific elements. The selection is based on the results of the current state analysis. These are marked separately in their own categories. In addition to these, many factories leave areas that will be the focus areas of the future. They are in the figure labeled as "others".

The third and final step is the *implementation guidelines*, which define the practical outcome of the areas in the model. The guidelines are general, but they facilitate the planning, resource allocation and performance of maintenance work at the sites. Each of these three phases as discussed in more detail later in this section.

## 5.2 Building the Framework (Findings of Data Collection 2)

The team of maintenance specialists was introduced into topic by illustration of the asset health care triangle by Peterson from 2006 taken from the conceptual framework. The workshop was in Finnish, but all materials were in English. All quotes have been translated to English by the author. The building of the generic frame of reference was started by selecting the pre-chosen elements from literature into the case company's own triangle. The workshop was conducted in such a way that these pre-selected elements were placed on a desk and each member of the team chose the most important focus areas for a functional maintenance model. Subsequently, the selected elements were placed on a blank triangle board so that they became mutually supportive, but scalable levels for development.

The elements chosen were largely the same, but there was much discussion about placing them on different levels of the triangle. *Spare parts and warehouse management* wanted to be in the first level, even though in the asset healthcare triangle it is at level 4. The Site Manager and Operations Manager commented as follows:

*Spare parts management is a basic thing. Without it, higher level functions cannot be effectively implemented. (Site Manager)*

*It must be part of daily work and requires continuous upkeeping (Operations Manager)*

After the final discussion, the *Spare parts and warehouse management* was decided to locate into the level 2.

Based on Data 2, The *Maintenance costs and KPI´s* focus area was divided into two parts, namely *Cost follow-up practices* and *Maintenance KPI´s.* The cost tracking is already in place very well in the operations areas north and central, as reported in the current state analysis. On the other hand, various maintenance indicators, such as the mean time between failure (MTBF) and mean time to repair (MTTR), also mentioned in the thesis literature part, require systematic data collection and reporting, representing a higher level of maturity in site operations.

*Maintenance costs and maintenance efficiency of which key performance indicators represent are partially independent elements. Monitoring performance metrics and building on them to drive performance is a higher level task. (Site Manager)*

In figure 8 below the final proposal of the framework is illustrated.

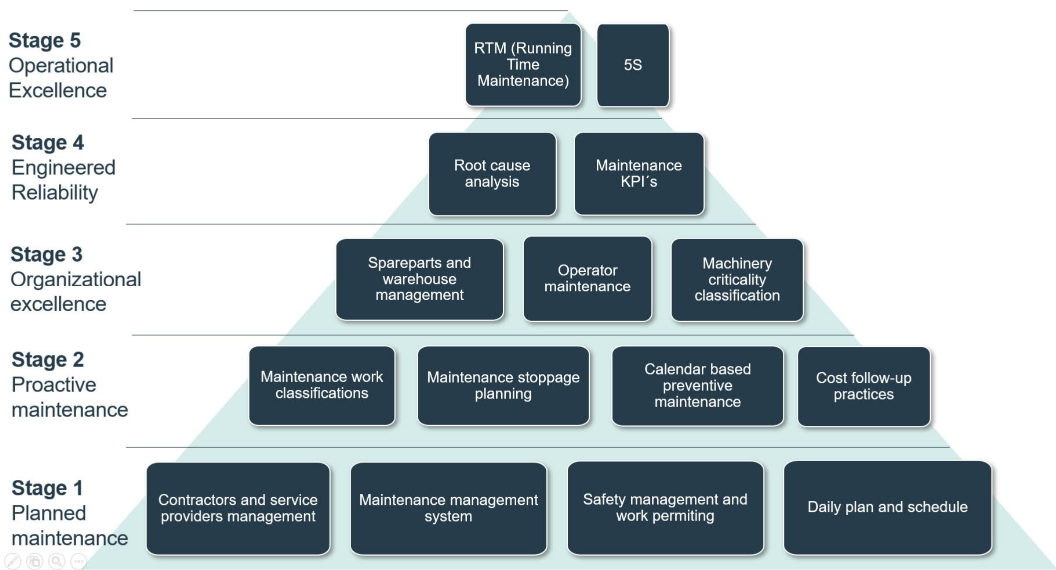


Figure 8. The case company´s maintenance framework

Figure 8 presents the five-level maintenance model framework in triangle shape. Each level represents the level of maturity of the case company's maintenance operations. The lowest-level elements are the core of maintenance operations and form the basis for more advanced operations. Each level also has a title that more generally describes a theme that combines different elements. The level headers reflect Peterson's 2006 presentation of the asset health care triangle. Unlike in the Peterson´s model, moving from one level to another does not require that all elements of that level to are "On Place", but defines the required input from the maintenance organization while also creating scalability in the model which will provide a roadmap for sites towards more advanced maintenance operations.

## 5.3 Selection Criteria (Findings of Data Collection 2)

After creating a common frame for all, the workshop focused on applying the results of the current state analysis in relation to frame to define focus areas. Due to differences in the degree of maturity of the sites, a bidirectional approach was taken to choose the focus areas. This approach is setting basis for criteria selection. The *selection criteria* includes elements which are common to all factories as well as factory specific elements.

The elements common for all of the factories are taken into consideration by reviewing strengths and weaknesses of existing maintenance operations in group level from table 7. below in figure 9. are illustrated all results from the current state analysis from where table 7 elements are derived.


Figure 9. Current state analysis results for all elements in group level

Figure 9 illustrates the distribution of the current state analysis results when all the answers of different sites of the case company are divided with the total number of sites. The color coding in the circle represents the part of which every element is “On Place” = green, “Planned to start” = yellow, “Not Doing” = red, and “Not known” = blue. From results top 4 elements can be identified for both “Planned to start” and “Not Doing” elements. Those elements are chosen for group level focus areas as stated in the Thesis current state analysis section.

However, the results from individual sites differ greatly from each other. This defines bidirectional approach where site specific results need to be taken into consideration in focus area selection as part of *selection criteria.* In figure 10 below the Eurajoki site specific results are shown with the same logic and color coding as the group level elements in figure 9. All site-specific results are shown in appendix 3.

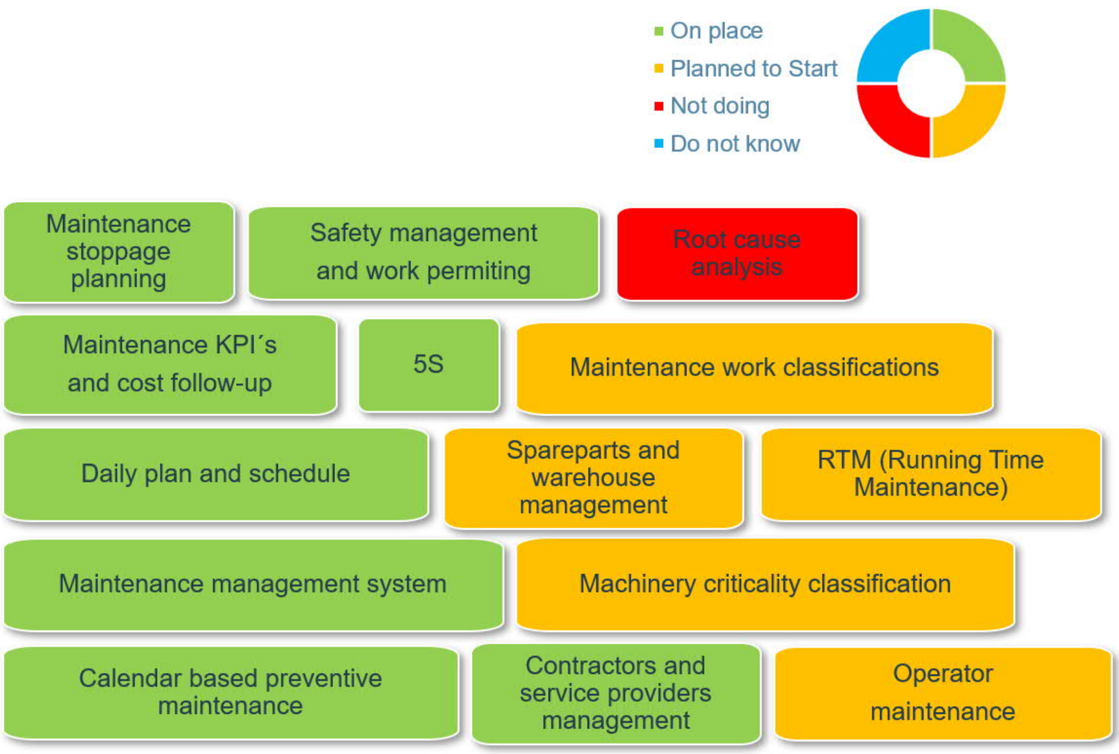


Figure 10. Eurajoki site specific current state analysis results for all elements

As shown in figure 10 above, the Eurajoki site represents an advanced level of maintenance operations. There are almost as many elements *On place* as in *not done* or *planned to start* together. The *Planned to start* -status was included to the questionnaire

to indicate site willingness to adapt new elements into maintenance practices. Now alignment between the group and the site-specific elements is needed. This alignment is part of *selection criteria* and follows the four rules explained below:

1. Group-level elements that also emerge at the factory specific results will be automatically included as part of the maintenance model.
2. Factory-specific elements are also selected into the model.
3. If the element is already *On place*, it will be included into the model.
4. Group-level elements that are in Stage 1 or Stage 2 **can** be taken into the model if the site has indicated the element as "planned to start"

The site-specific example of the final proposal of selected focus areas based on *selection criteria* in the case company´s maintenance framework is shown in figure 11 below.

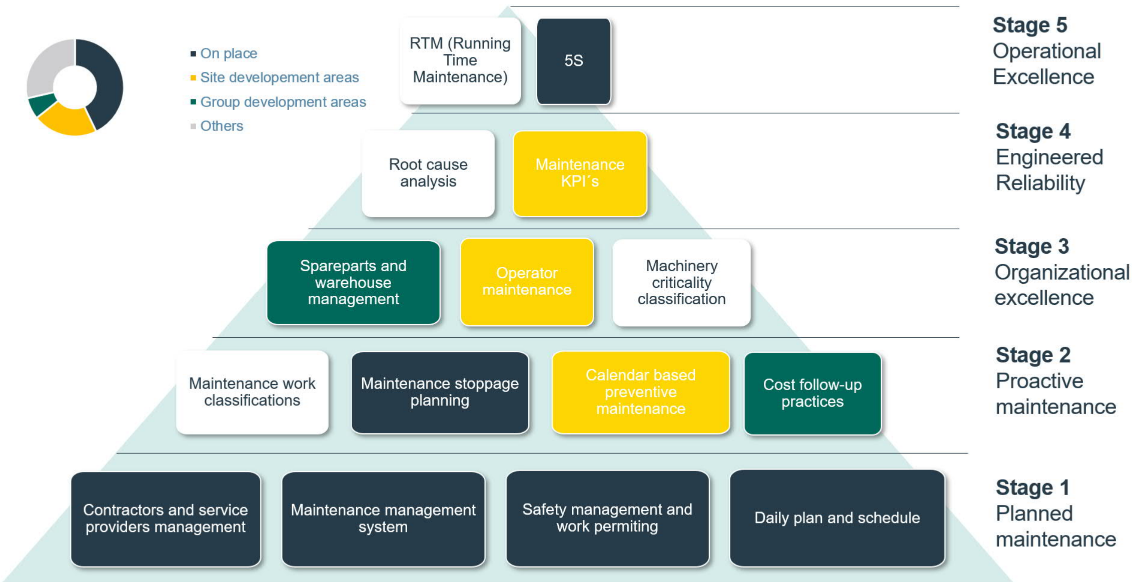


Figure 11. Eurajoki site specific focus areas based on maintenance model selection criteria.

As can be seen from figure 11 above, the elements have been placed into triangle frame. The color coding shows the origin of individual elements according to *selection criteria* Blue is representing the elements that are *On place*. Yellow and dark green are showing

whether the element is chosen based on group level or site-specific objectives. The elements without color are left out from the model but will provide a roadmap for the sites towards more advanced maintenance operations.

The stages from 1 to 5 are showing the required commitment and input from the maintenance organization while also creating scalability in the model. According to the selection criteria, elements from each level should be selected for the model. This also supports target setting with ambition to raising maintenance levels. In other words, the factory cannot stay at its current level. The framework described in chapter 5.2 together with the *selection criteria* will make it possible to create a site-specific model for each factory. A summary of the relationships between the focus area selection criteria is illustrated in figure 12 below.

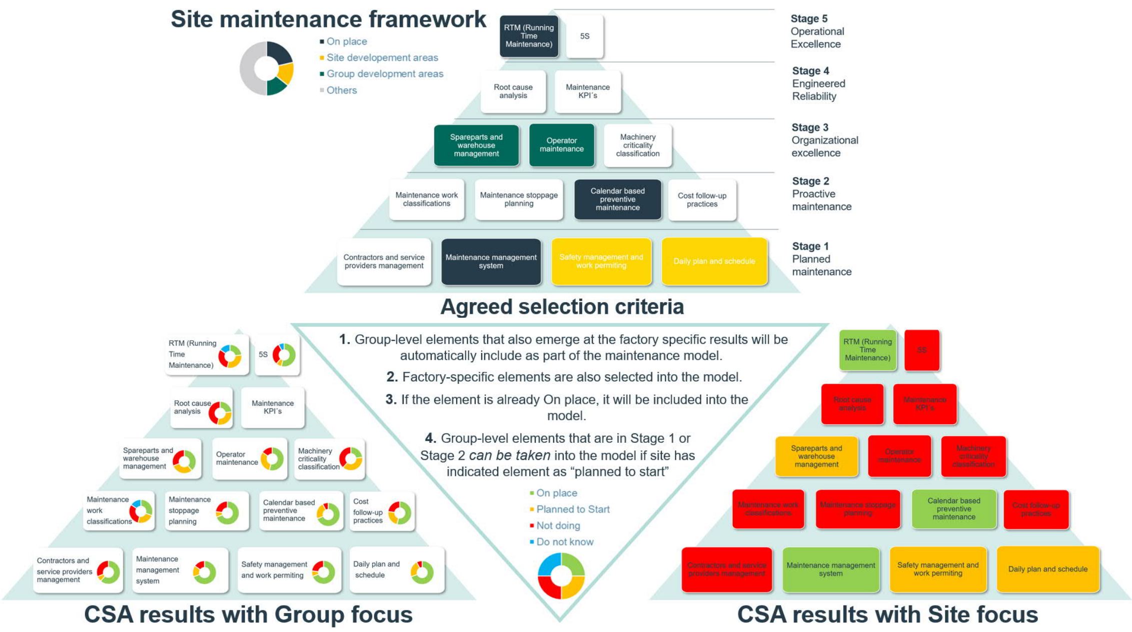


Figure 12. The focus area selection criteria summary

As illustrated in Figure 12, the current state analysis results are placed into the triangle framework as abasis of the focus area selection. The group level focus areas are on left and site specific on the right. With the help of the agreed selection criteria, shown in the middle, the elements are chosen into the site maintenance framework positioned up in the middle.

## 5.4 Implementation Guidelines (Findings of Data Collection 2)

It is crucial for the sites to have understanding what the maintenance model provides in practice. Each element is targeting to improve certain areas in the maintenance operations and there are measures to follow-up development and performance. The categorization was introduced and developed further in the workshop. The common view was that, since the performance of many elements is measured by the value of the maintenance costs, reporting practices need to be harmonized to enable comparison between sites. The Maintenance engineer commented as follows:

> *Cost follow up principles to be aligned between North and Central operations (Maintenance engineer)*

As a side note, the definition of a common root cause analysis tool was highlighted. A similar approach for analyzing the root causes of the problem makes it possible to properly allocate maintenance resources.

> *Common tool for root cause analysis is needed (Maintenance engineer)*

Below the table of proposal draft can be found to explain the relation between objective, chosen element and outcome including measures for follow-up.

Table 9. Implementation guidelines

| **Objectives** *of maintenance activities* | **Elements** *Adapted from key concepts* | **Outcome** | **Measures** |
|---|---|---|---|
| Efficient day-to-day maintenance practices | Daily plan and schedule | Reduced maintenance costs and increased machine availability | Maintenance costs and number of offline hours |
| | Spareparts and warehouse management | | Maintenance costs |
| | Contractors and service management | | Maintenance costs |
| | Maintenance management system | Cost efficient and best-fit maintenance plans | Maintenance costs and number of offline hours |
| | RTM (Running Time Maintenance) | | Average error interval statistics |
| | Maintenance KPI´s and cost follow-up | | Maintenance costs |
| Systematic fault and disturbance monitoring | Operator maintenance | | Maintenance costs |
| | Root cause analysis | Correctly allocated maintenance activities | Average error interval statistics |
| | 5S | | Maintenance costs and number of offline hours |
| | Calendar based preventive maintenance | | Maintenance costs |
| Guides and instructions for maintenance planning | Machinery criticality classification | | Average error interval statistics |
| | Safety management and work permiting | Cost efficient and best-fit maintenance plans | LTA1, MTR |
| | Maintenance work classifications | | Maintenance costs |
| | Maintenance stoppage planning | | Maintenance costs |

As can been in table 9 above, the elements are categorized according to two different aspects. The left-hand column lists the three main topics of maintenance that fundamental for efficient maintenance activities. To the right of the elements, column three lists the benefits what can be achieved utilizing the chosen elements. The last column on the right shows the measures for indicating the performance of individual elements under these categories.

## 5.5 Proposal Draft

The proposal draft combines the different parts into the maintenance model illustrated as a phased process. The common focus areas within the Group together with the factory-specific areas are taken into account and placed into the frame according to the selection criteria. The outcome of the model, the factory-specific maintenance framework is supported with the implementation guidelines to enable performance management. The visualization of the draft proposal is shown in figure 13 on the next page.

The proposed model creates a factory-specific and scalable model for managing and developing maintenance in the case company. The arrows represent the connection of various elements to the origin of the frame. In the upper right corner is the result of the model, below are the implementation guidelines that can be used to manage performance. In the next section, the validation of the model is discussed.

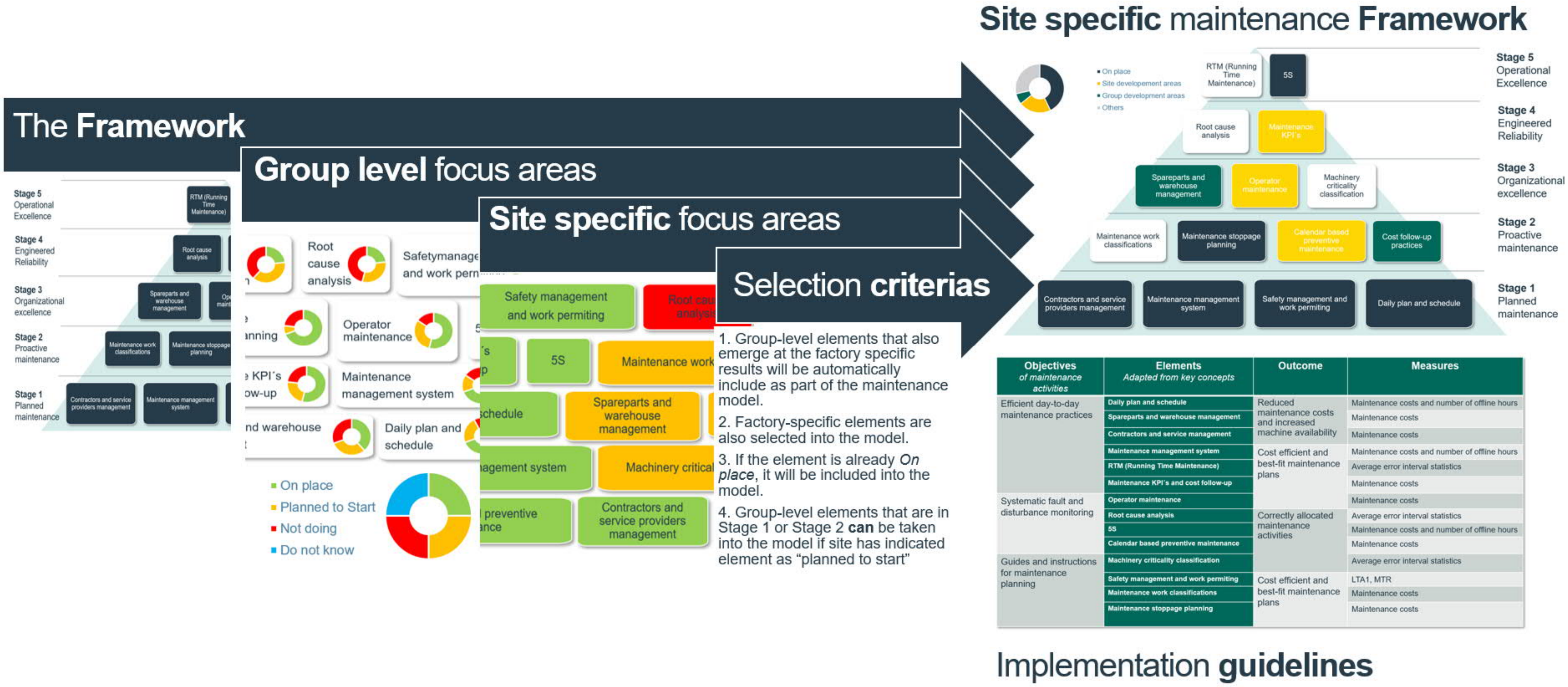


Figure 13. The content of the scalable maintenance model draft proposal for the case company

# 6 Validation of the Proposal

This section reports on the results of the validation stage and points to further developments and additions to the initial Proposal. At the end of this section, the final proposal and recommendations are presented.

## 6.1 Overview of the Validation Stage

This section validates the proposal of scalable maintenance model developed in Section 5. The validation process was done by piloting the building process of the site-specific maintenance frameworks with the help of the model. The framework was built for each site and then presented to the organization’s management.

The aim of this section is to evaluate functionality of the model by piloting site specific maintenance framework building process step by step and to present the frameworks to the operations directors of the case company. The order of the validation process was chosen to pilot the model first to give to the management a concrete example of the solution provided by the model in their own area of responsibility. The proposal building in section 5 followed the model steps and included the data gathering from the current state analysis. The site-specific maintenance framework was built gradually step by step. Therefore, the validation process follows the same principle including feedback from the management as the last part. Furthermore, the recommendations are summarized for model improvements.

## 6.2 Building the Site-specific Maintenance Frameworks

The co-created triangle framework was taken as basis for focus area selection. The common development areas of the group which were discovered in the current state analysis, was placed into triangle framework. Next, site-specific results was compared within the framework. From these, the elements into the site-specific maintenance framework were selected according to the criteria. Figures 14, 15 and 16 illustrate steps of the process when building the site-specific maintenance framework according to the model.

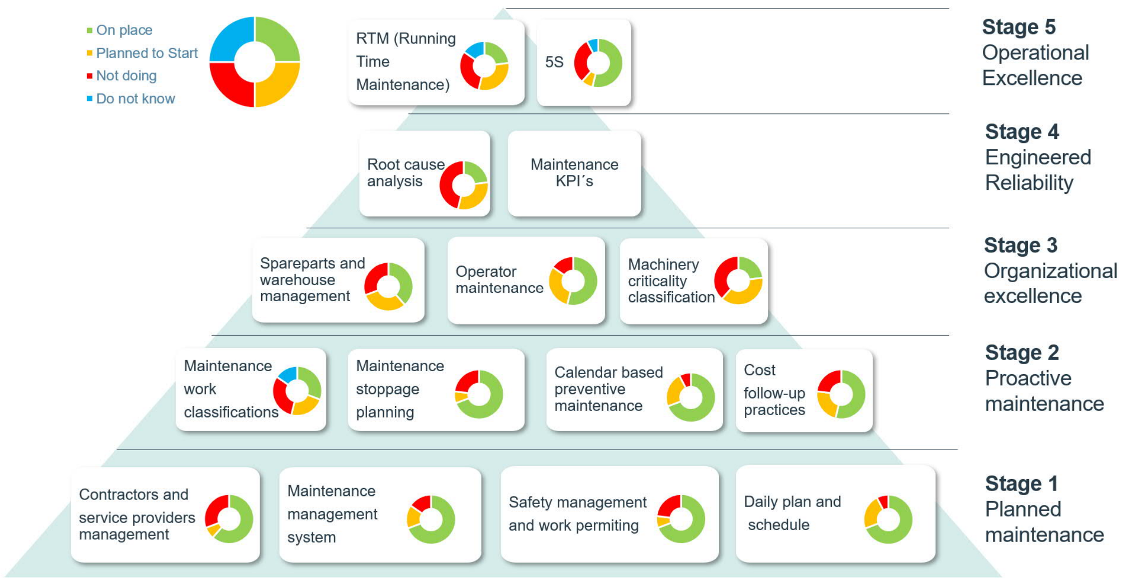


Figure 14. Step 1 of the model when building the site-specific maintenance network for De Lier factory - The common development areas of the group

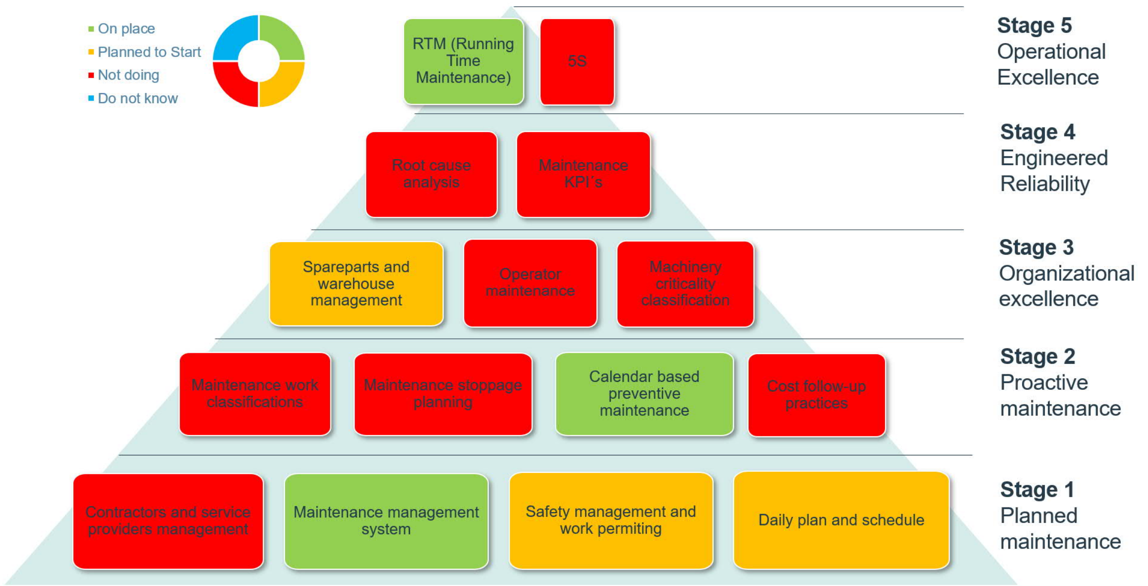


Figure 15. Step 2 of the model when building the site-specific maintenance network for De Lier factory - The site-specific development areas

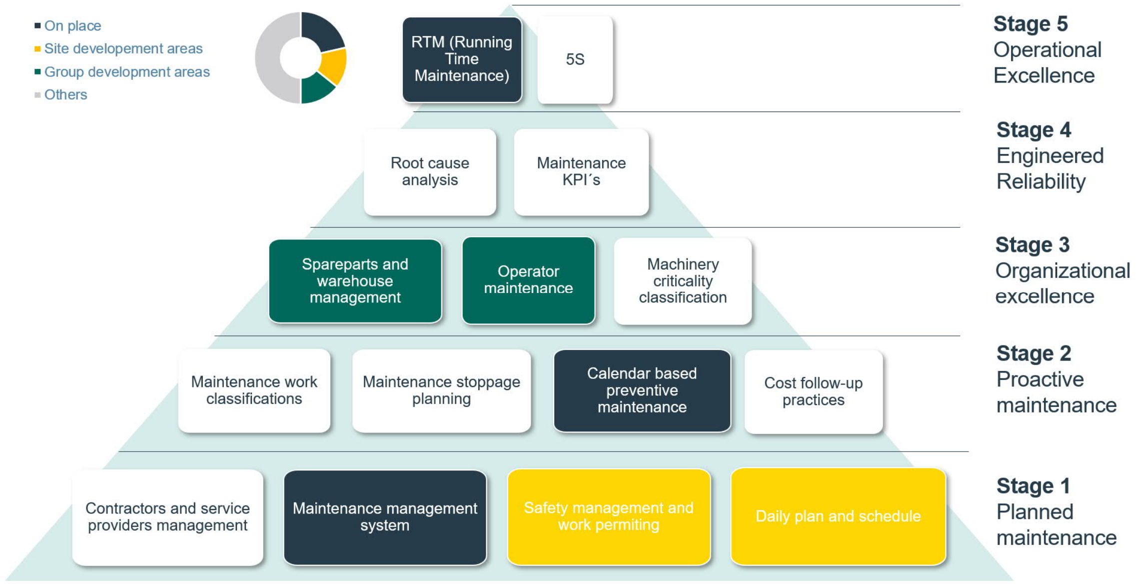


Figure 16. Step 3 of the model when building the site-specific maintenance network for De Lier factory - The site-specific maintenance framework selected according the criteria.

As can be seen in figure 16, the maintenance framework for De Lier factory differs from the maintenance framework built for Eurajoki site in Section 5. The operating practices between factories differ also including maintenance organization. The elements left out from De Lier framework represent 50% of total elements. This validates the scalability of the model by offering less elements to focus for factories which are just starting to apply the model. This way, factories can be familiarized with the model without jeopardizing the other day-to-day activities with overwhelming workload. However, the *other* elements guide the long-term development of the site's maintenance activities. All site-specific maintenance frameworks can be found from appendix 4.

## 6.3 Management Feedback

The scalable maintenance model was presented in management review to the three Operations directors who are responsible for all sites of the case company and improvement ideas as well as requests to additional features were received.

The management suggested that the aim of the thematic survey should have been communicated more clearly beforehand and re-evaluation should be done after the model and concept is taken into use. This suggestion will be implemented to the model by adding annual assessment of the group and site-specific focus areas.

The importance of the maintenance management system (CMMS) was highlighted. The common maintenance tool will create common ground for maintenance work and guides the implementation of elements in a similar way. The Operations Directors commented as follows:

> *Mutual computerized maintenance management system (CMMS) tool should be priority for all factories (Operations Director Central)*

Based on the feedback, the CMMS will be added to all site-specific maintenance frameworks. The operations area North will start the implementation of the model as a pilot and basic template for action planning and follow up was requested to be added into the model.

> *The model will be presented to all site managers and they are expected to commit chosen elements in their maintenance activities (Operations Director North)*

According to the feedback, the basic template for implementation activity planning will be added as tool to the maintenance model. The template includes selected objectives from the maintenance framework with planned site-specific action and responsible persons. in addition the implementation schedule and status are recorded for monitoring and guidance. The template is presented as table 10 below.

Table 10. Action planning template for model implementation planning and follow-up

| Objective | Action | Ready by | Responsible person | Comments / Status |
|---|---|---|---|---|
| Calendar based preventive maintenance | -Creating maintenance programs for machinery<br>-Generating maintenance tasks | 02/2020<br>04/2020 | N.N. | Good example of work management and reporting. No lag or delays |
| Daily plan and schedule | -Daily tasks visible in Novi (resources and equipment)<br>-Daily reporting into Novi on place | 04/2020<br>07/2020 | N.N. | Work management and reporting in good level. Calendar maintenance still in minority |
| Operator maintenance | -Establishing operator maintenance tasks (Route maintenance<br>-Training the operators | 02/2020<br>07/2020 | N.N. | Modest amount of work in Novi. Only route maintenances in use. |
| Spareparts and warehouse management | -Establishing warehouses to Novi<br>-Creating the items<br>-Inventory counting | 02/2020<br>04/2020<br>07/2020 | N.N. | Work management in OK level. Calendar maintenance not planned. |
| RTM (Running Time Maintenance) | -Concept of RTM<br>-Check the readiness of existing equipment | 06/2020<br>08/2020 | Tapani Aavikko | Work management and reporting in good level. Mainly maintenance. |

To be estabished for each site

As can be seen in table 10, the objectives are in the left column one below the other. The following column is titled as an action referring to the planned activities how to take the objective into use. The content of action is depending on the site maintenance organization´s size and competence. In other words, the action is always site specific and should be planned together with local site organization. The template also guides to nominate a responsible person and set the due date for action. The final column on the left is meant for follow-up done monthly.

## 6.4 Finalized Scalable Maintenance Model

The scalable maintenance model has been tested by building site-specific maintenance frameworks to each site. It has also been presented to the case company stakeholders. As a result, the improvement ideas were provided in a form of annual assessment of the focus areas. The Group and site-specific focus areas are evaluated annually to ensure that the model does not expire. The criteria can be modified as needed when the level of the activities in the triangle rises to the next stages.

Moreover, add-on requests were suggested related to the group wide CMMS and action planning template. Furthermore, the model functionality as tool for building site-specific maintenance frameworks revealed that the *selection criteria* are valid and do not provide excessive load to local organizations. Overall, the model works well and thesis objective to build a scalable maintenance model for the case company has been fulfilled as the model will takes into consideration the case company´s different levels of maintenance practices and scales as needed. The final model is presented in figure 17 on next page.

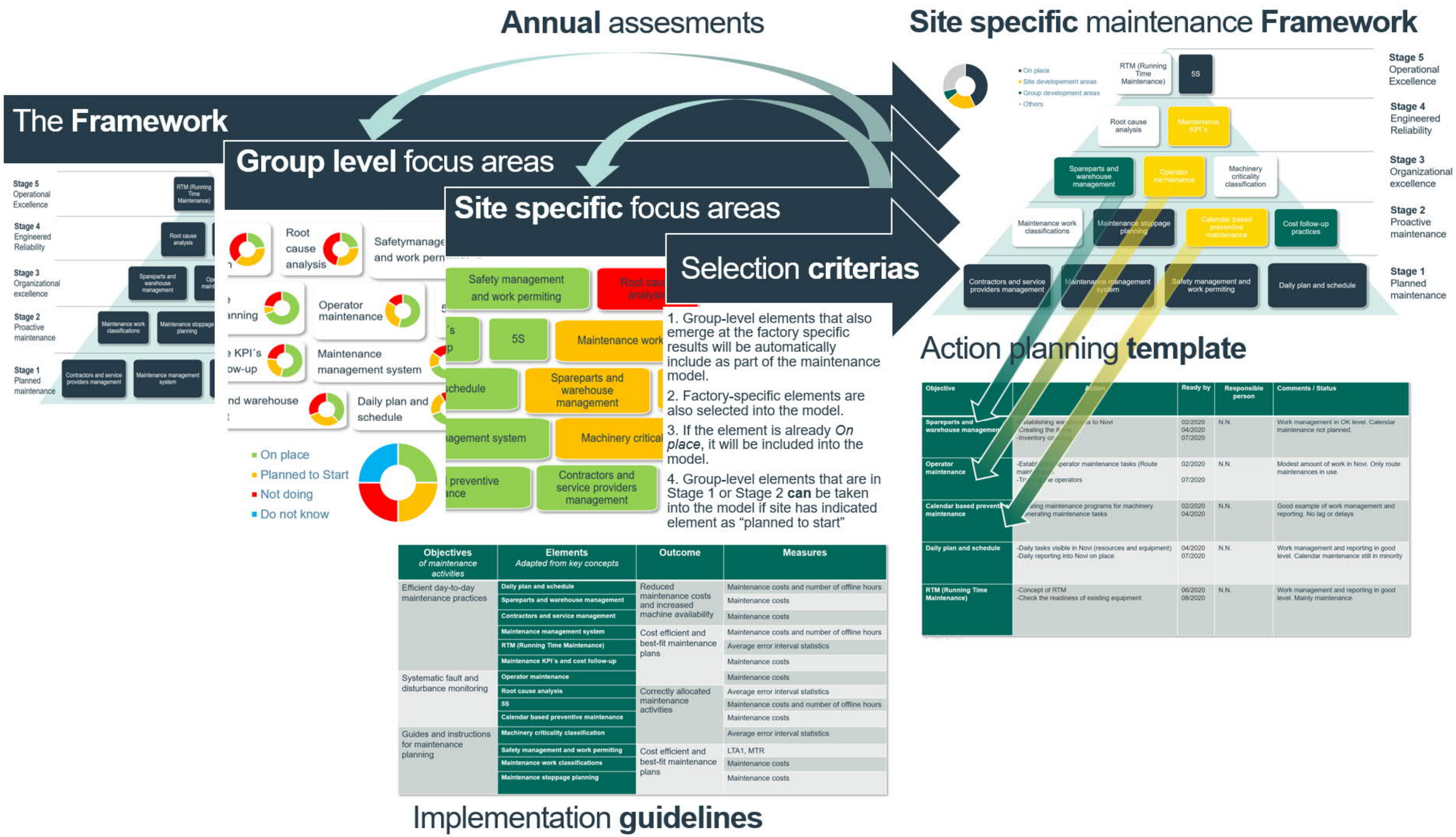


Figure 17. The content of the scalable maintenance model for the case company

## 6.5 Recommendations for the Case Company

This section provides recommendations for the company to develop its maintenance activities based on the findings made at different stages of the thesis work. The subjects of these recommendations were not part of the scope of the thesis.

### 6.5.1 Site Specific Operating Process Descriptions

One of the shortcomings and differences between the factories identified in the current status analysis were the process descriptions of floor level maintenance activities. These descriptions were found for the maintenance organization of the Eurajoki site. The process descriptions were arranged for the site-specific operating environment but were not available for the other sites. The processes described are not directly applicable to other factories, but they are a good starting point to describe other sites as well.

The factory-specific process descriptions can be used to more precisely define the performance of the different types of maintenance work. They also support the implementation of the computerized maintenance management system which was prioritized by management to clarifying the roles and related work tasks. The process descriptions allow the maintenance organization to reorganize maintenance tasks at a later stage.

### 6.5.2 Harmonized Maintenance Costs Reporting Practices

Maintenance cost reporting between the north and the central operations differs. The north operation monitors costs at the account level, providing a view of used spare parts and maintenance costs. Central operations allocate all costs to equipment level that allows for machine-specific cost analysis.

These different reporting practices should be harmonized. Either so that in the future all machines would have an account-level view, or either policy could be chosen as common. This enables internal benchmarking of maintenance, based on which economically best practices could be implemented between factories. Now, this comparison cannot be made reliably, nor can it be said whether another practice is better than another in terms of cost.

In the next chapter the conclusions of the thesis study are presented and thesis evaluation criteria are discussed.

# 7 Conclusions

This section summarizes the thesis study and the developed scalable maintenance model proposal followed by the thesis evaluation criteria and closing words.

## 7.1 Executive Summary

The objective of this study was *to develop a scalable maintenance model* for the case company, which is suitable for different size production units whose business focus is also different. The need for the model emerged from a newly established joint venture where factory maintenance operating practices differ between new partners. Aligning these practices and implementing best fit maintenance procedures would keep up machine efficiency when increasing volumes are expected for the coming years.

The study was conducted according to the design research approach and started with the relevant literature review for best practices on maintenance model building. The current state analysis of the maturity level of maintenance related operations was based on the conceptual framework and was done as thematic internal survey. The current state analysis included also cost/quality structures. The gap analysis was performed on tactical level. The guidelines for the maintenance model were co-created with the case company key individuals based on literature and gap analysis. The proposal for the scalable maintenance model was introduced for validation with different maturity levels within the case organization.

From literature, best available industry practices were searched as a basis for current state analysis and model proposal development. The first element was the strategic alignment of the maintenance model. It was found that the proactive strategy (preventive and predictive maintenance) as the basis for the maintenance strategy of the company would be the most beneficial approach. The second element from literature were the different maintenance models described as best practices suitable for a chosen strategy. A study by Fraser et al. from 2015 revealed the most used models for preventive maintenance. It was also found that even a single company can have elements of different models and concepts at their disposal. This type of multiple practices was chosen as the approach for this study. The focus was on a world-class maintenance concept as the enhanced version of Total Productive Maintenance including elements also from Condition Based Maintenance. The third element taken from literature was scalability of

maintenance model. By placing the functional elements of the different maintenance models into a triangle model pyramid by Peterson, the elements will have a vertical dimension that can be used to scale the model for different maturity levels of factories and operations.

These key concepts from literature were then the basis for a current state and gap analysis of the maintenance model as well as model development. The maturity level of the sites was found to be very fragmented. A small number of factories master the basic maintenance operations and the rest of the factories use only single elements from the ideal model. The maintenance cost structures did not provide accurate enough information to draw conclusions. The cost allocation and organizational differences created too much uncertainty. For that reason, the cost structures were not included into the development of the maintenance model. Also detailed maintenance operating procedures were described only in Finland in the North operating area. These process descriptions will provide good working instructions for the local organization but are specific to the operating environment and organization and thus cannot serve as a basis for the entire maintenance model for the case company. Based on the current state analysis, the lowest common denominator for developing a common maintenance model for the case company was the utilization of strengths and weaknesses from the maturity level analysis.

The initial proposal for the scalable maintenance model embraced four parts. The proposal draft consists of the *framework*, *selection criteria*, *site maintenance framework* and *implementation guidelines*. The common focus areas within the Group together with the factory-specific areas were taken into account and placed into the *framework* according to the *selection criteria*. The outcome of the model, the *site maintenance framework* will be supported with the *implementation guidelines* to enable performance management.

The first part of the model proposal is the *framework* built from best practice elements found from literature. The elements selected into the frame represent the most appropriate areas of activity chosen by the case company representatives. The elements fall into five different stages according to the need of effort and competence from the maintenance organizations. The lowest-level elements are the core of the maintenance operations and form the basis for more advanced operations.

The second part in the model proposal is *selection criteria* for focus areas. These focus areas are selected from the elements common to the Group as well as from site-specific elements. The elements are based on the results of the current state analysis. The Alignment between the group and the site-specific elements follows four rules explained below:

- Group-level elements that also emerge at the factory specific results will be automatically include as part of the maintenance model.
- Factory-specific elements are also selected into the model.
- If the element is already in use, it will be included into the model.
- Group-level elements that are in Stage 1 or Stage 2 in the framework **can** be taken into the model if site has indicated willingness to utilize that particular element.

In addition to these, for many factories some elements remain that will be the focus areas of the future. As an end result of *selection criteria* execution, the *site maintenance framework* can be established.

The last part of the model proposal consists of the *implementation guidelines*, which define the practical outcome of the focus areas in the *site maintenance framework*. The guidelines are general, but they facilitate the planning, resource allocation and performance management of maintenance work at the sites.

The initial proposal of the scalable maintenance model was presented to the case organization’s management of the case company for feedback and improvement suggestions. The *site maintenance framework* was first built for each site as piloting the functionality of the model and then presented to the Operations directors. Based on feedback the annual assessment of the Group and site-specific focus areas was included into the model together with an action planning template. Also, computer managed maintenance system (CMMS) was set as focus area to every site.

Implementing the common maintenance model will raise the level of asset management remarkably. It will prepare production for the upcoming years ensuring the basis for the profitable growth of the case company. Currently the outcome of maintenance activities is not sufficient to keep up machine efficiency when increasing volumes are expected for the coming years.

## 7.2 Next Steps and Recommendations Toward Implementation

The first step towards implementing the maintenance model is to validate the site-specific maintenance frameworks build with the help of the model. This requires local maintenance organizations to focus on the more specific content of the elements as well as management support for the project. In this context, commitment to agreed targets should also be encouraged. This could be done by measuring progress with KPIs in the model and linking them to the reward programs.

At a practical level after validation, the implementation and use of a common maintenance software tool could be the target that would first bring consistency in maintenance activities between all 12 sites. The CMMS was defined as the focus area for all and its use steers the harmonization with several elements of the model. The diagram below shows the coverage of the common maintenance program from the elements of the general maintenance frame of reference.

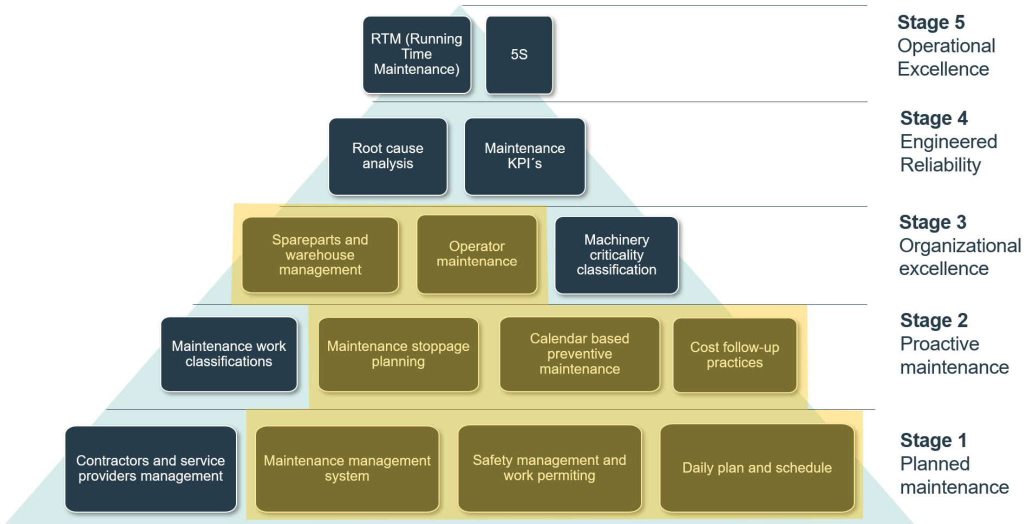


Figure 18. The case company´s maintenance framework with CMMS coverage

In figure 18 the yellow transparent color represents the CMMS solution coverage of the elements chosen into maintenance framework. As can be seen it would cover fully or partly 8 elements out of 15 in maintenance framework creating a good basis for a harmonized model.

With these two activities, the implementation of the model would be initiated quickly and concretely. The usage of a common software tool also brings “quick wins” to local maintenance organizations by bringing clarity into daily activities.

### 7.3 Thesis Evaluation

The aim of the thesis was to develop the scalable maintenance model based on best industrial practices from literature as well as the current state of the case company's maintenance operations. The thesis started with literature review and proceeded with co-creating the initial proposal with the case company representatives. Based on the feedback from the case company management, the final proposal was concluded, achieving the initial objective and outcome. This section discusses and evaluates the credibility criteria of this thesis in terms of *validity, reliability, logic* and *relevance.*

According to literature the validity of research can be evaluated from different points of views. Based on Bryman & Bell, 2005, Internal validity refers to how well the study has been conducted and how well it answers to the challenge at hand. One of the main methods to ensure validity is triangulation. (Patton 2005) He mentions for example methodological triangulation and refers to using multiple methods, such as qualitative and quantitative. Also using several approaches to data collection, for example interviews and surveys among text will provide more than single approaches. Data triangulation can be achieved by having multiple informants and documents from different times.

The *validity* in this thesis was built on using several different data collection methods. The data collection was done through surveys, workshops and interviews with managers, specialists and other stakeholders. Internal validity was ensured by giving the opportunity to the stakeholders to be part of the co-creation of the model and review the proposal draft with the case company decision makers.

The *reliability* of the study comes from transparent data management. The data sources, data collection and data analysis are clearly set out, including the rationale behind choices (Creswell & Millar 2000). The results of data collection are stored in an organized way and documented methods for collecting data enables the possibility to replicate data gathering as well as follow the trail of evidence.

In this thesis the documentation of the survey, both questions and answers are available providing full transparency. The reliability is also supported by triangulation. The response to the survey took place as an individual performance of the specialist from different roles in the maintenance organization and without their position affecting the weight of the result evaluation.

The *logic* in thesis study refers to an approach where the chain of evidence can be pointed out from consequent steps taken to achieve results related to the addressed business challenge. The logic of this study is built into the structure in such a that each

section´s outcome provides the basis for the next sections. The conceptual framework interconnects the current state analysis. The identified strengths and weaknesses from the current state analysis and conceptual framework provide the basis for the proposal draft. In the final stage, the proposal draft was introduced to key stakeholders and based on the feedback the final proposal was built.

The *relevance* of research determines the importance of the research to the case company and the contribution to the research objective (Quinton and Smallbone 2006). The objective of this thesis is based on a real-life business challenge of the case company. The key stakeholders in the case company have contributed to the development of the outcome and expressed their willingness to implement the created model proposal. The theory of the research is based on the literature and the created model provides generally valid guidelines to be utilized outside the case company for maintenance development activities. The *relevance* of the study and the model proposal can be verified only after a sufficient number of production sites have adopted the model into use.

## 7.4 Closing Words

More food production is needed to feed the growing population. Greenhouse cultivation and home growing are expected to increase strongly in the coming decades. This requires premium substrates provided by the case company. As production volumes increase, production equipment must be taken care of with higher quality and in a more efficient way. The *scalable maintenance model* now proposed provides the one element more to asset management for the case company to ensure future profitability growth without costly repair investments enabling also higher availability of production equipment.

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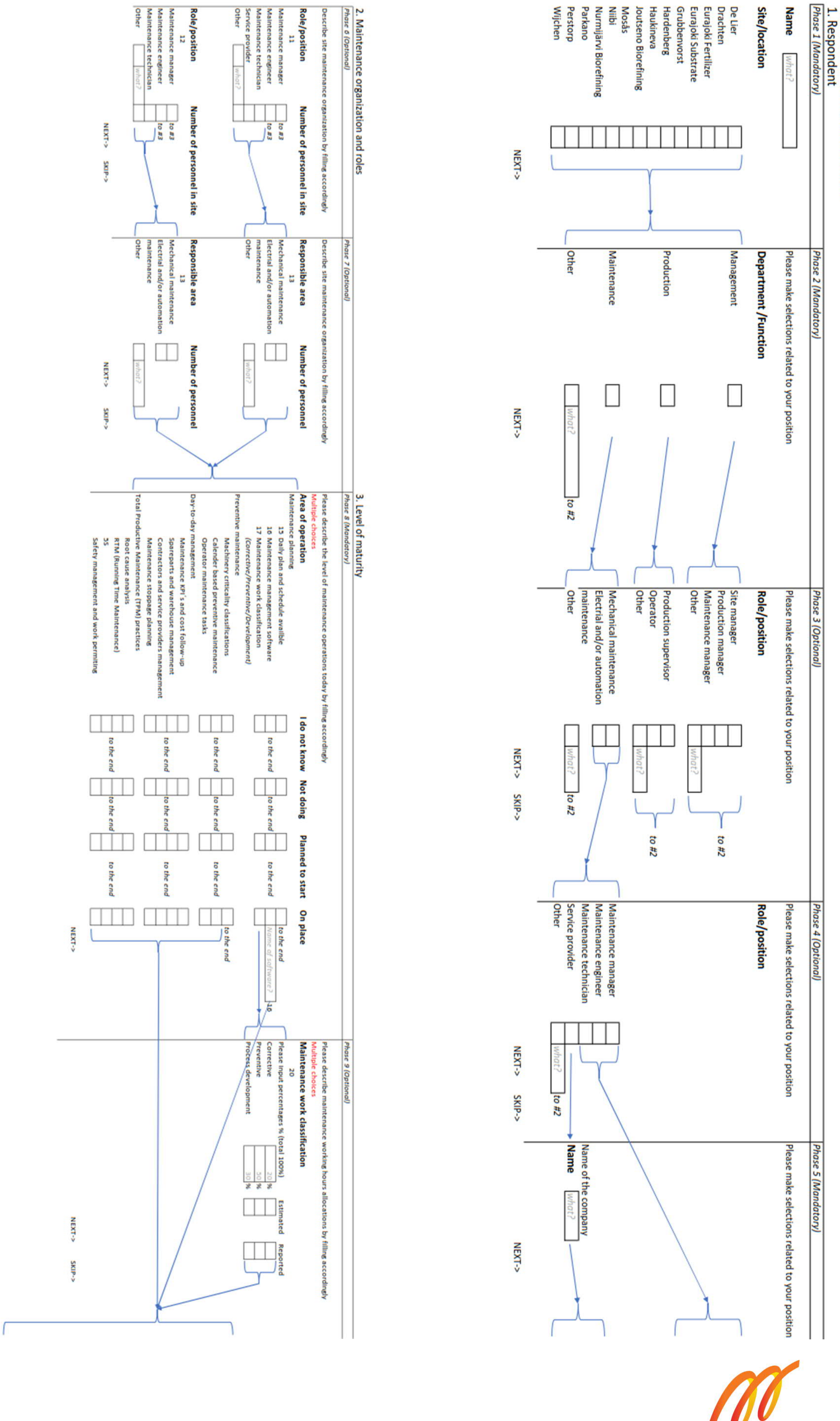
## The questions for the thematic internal survey

| Question | Selection |
|---|---|
| Respondent name | Name |
| Select site/location | |
| Department / function | |
| Role/position | |
| Name of the Service Provider Company | Name |
| Number of personnel in this site per position or role | Maintenance manager |
| | Maintenance engineer |
| | Maintenance technician |
| | Service provider |
| | Other, what |
| Number of personnel in this site per position or role working with service provider | Maintenance manager |
| | Maintenance engineer |
| | Maintenance technician |
| | Other, what |
| Number of personnel in site per specific area | Mechanical maintenance |
| | Electrial and/or automation maintenance |
| | Other, what |
| Area of operation: Maintenance planning - Daily plan and schedule available | |
| Area of operation: Maintenance planning - Maintenance management software | |
| Name of the software in use? | name |
| Area of operation: Maintenance planning - Maintenance work classifications (Corrective/Preventive/Process development) | |
| Please describe maintenance working hours allocations by filling accordingly | Corrective -- 20% |
| | Preventive -- 50% |
| | Process development -- 30% |
| Area of operation: Preventive maintenance - Machinery criticality analysis | |
| Area of operation: Preventive maintenance - Calendar based preventive maintenance | |
| Solution /method for preventive maintenance | |
| Name of the dedicated software for calendar based preventive maintenance? | |
| Please describe other methods in use? | |
| Area of operation: Preventive maintenance - Operator maintenance tasks | |
| Solution /method for preventive maintenance - Operator maintenance tasks | |
| Name of the dedicated software | |
| Please describe other methods in use? | |
| Area of operation: Day-to-day management - Maintenance KPI´s and cost follow-up | |
| Solution /method for Maintenance KPI´s and cost follow-up | |
| Name of the dedicated software for Maintenance KPI´s and cost follow-up | |
| What other method is in use? | |
| Area of operation: Day-to-day management - Spareparts and warehouse management | |
| Solution /method for Spareparts and warehouse management | |
| Name of the dedicated software for Spareparts and warehouse management | |
| What other method is in use? | |
| Area of operation: Day-to-day management - Contractors and service providers management | |
| Area of operation: Day-to-day management - Maintenance stoppage planning | |
| Area of operation: Total Productive Maintenance (TPM) practices - Root cause analysis | |
| Solution /method for Root cause analysis (RCA) | |
| Name of the dedicated software for Root cause analysis (RCA) | |
| Please describe other methods in use? | |
| Area of operation: Total Productive Maintenance (TPM) practices - RTM (Running Time Maintenance) | |
| Area of operation: Total Productive Maintenance (TPM) practices - 5S (Sort, Set in order, Shine, Standardize, Sustain) | |
| Any good observations to share related 5S practices? | |
| Area of operation: Total Productive Maintenance (TPM) practices - Safety management and work permitting | |
| Please describe how the maintenance or repair work permitting is done to ensure work safety? | |
| Area of operation: Are you practicing activities in area of continuous improvement in maintenance operations? | |
| | Predictive maintenance |
| | EAM (Enterprise asset management) |
| | System integrations has been built |
| | Other, what |
| Area of operation: Continuous improvement in maintenance operations - systems integrations | |
| Please name systems and describe relations between those? | |

**The step-by-step process of the internal thematic survey.**



*Phase 10 (Optional)*

Please describe the tools for maintenance operations today by filling accordingly
Multiple choices

**Solution /method for preventive maintenance**

| 21 | Paper notes | | Excel | | Lean (e.g. T-cards) | | Other method | 24 | Dedicated software | Name 25 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Calender based preventive maintenance | | to the end | | to the end | | to the end | what? | to the end | | what? | to the end |
| Operator maintenance tasks | | | | | | | what? | | | what? | |

**Solutions /methods for Day-to-day management**

| 22 | Paper notes | | Excel | | Lean (e.g. T-cards) | | Other method | 24 | Dedicated software | Name 25 |
|---|---|---|---|---|---|---|---|---|---|---|
| Maintenance KPI´s and cost follow-up | | to #4 | | to #4 | | to #4 | what? | to #4 | | what? |
| Spareparts and warehouse management | | | | | | | what? | | | what? |
| Contractors and service providers management | | | | | | | what? | | | what? |
| Maintenance stoppage planning | | | | | | | what? | | | what? |

**Solution /method for Total Productive Maintenance (TPM) practices**

| 23 | Paper notes | | Excel | | Lean (e.g. T-cards) | | Other method | 24 | Dedicated software | Name 25 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Root cause analysis | | to the end | | to the end | | to the end | what? | to the end | | what? | to the end |
| RTM (Running Time Maintenance) | | | | | | | what? | | | what? | |
| 5S | | | | | | | what? | | | what? | |
| Safety management and work permiting | | | | | | | what? | | | what? | |

NEXT-> SKIP->

**4.Maintenance Key Preformance indicators**

*Phase 11 (Optional)*

Please report the maintenance performace indicators by filling accordingly
Multiple choices

**Maintenance costs (1000 x €)**

| | Budget for 2019 | YTD 2019 | Total year 2018 | |
|---|---|---|---|---|
| Spareparts | x 1000€ | x 1000€ | x 1000€ | to the end |
| Salaries | x 1000€ | x 1000€ | x 1000€ | |
| Services | x 1000€ | x 1000€ | x 1000€ | |
| Total | SUM x 1000€ | SUM x 1000€ | SUM x 1000€ | |

**Total costs relation to production volumes**

| Total costs 2018 | Total volumes 2018 | % of volume |
|---|---|---|
| SUM x 1000€ | Enter volumes | #ARVO! |

**Volume in table is in**

| | | |
|---|---|---|
| Bags | | to the end |
| Pallets | | |
| EN Cubics | | |
| Loose cubics | | |
| Other | what? | |

**Offline / error hours**

| | YTD 2019 | Total year 2018 |
|---|---|---|
| Online hours | Enter hours | Enter hours |
| Offline hours | SUM of error and othe | SUM of error and othe |
| Error hours | Enter hours | Enter hours |
| Other offline hours | Enter hours | Enter hours |

NEXT-> SKIP->

**5.The end**

*Phase 12 (Mandatory)*

Thank you!

SEND->

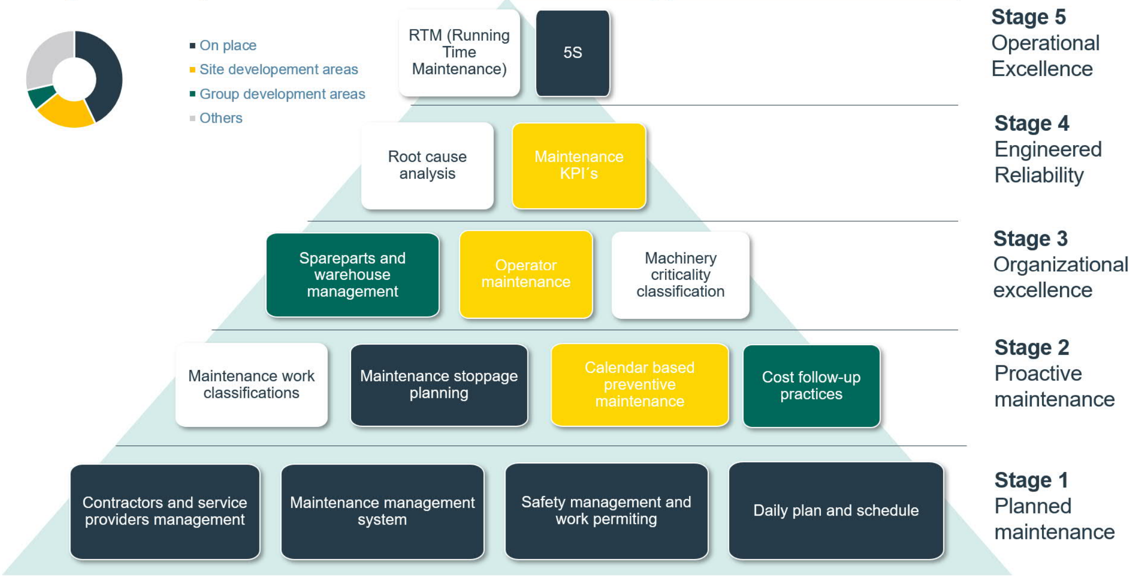
# The results of the thematic internal survey

| 3. Select site/location | 15. Area of operation: Maintenance planning - Daily plan and schedule available | moodi | 16. Area of operation: Maintenance planning - Maintenance management software | moodi | 18. Area of operation: Maintenance planning - Maintenance work classifications (Corrective/Preventive/Process development) | moodi | 20. Area of operation: Preventive maintenance - Machinery criticality analysis | moodi | 21. Area of operation: Preventive maintenance - Calendar based preventive maintenance | moodi | 25. Area of operation: Preventive maintenance - Operator maintenance tasks | moodi | 29. Area of operation: Day-to-day management - Maintenance KPI´s and cost follow-up | moodi |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parkano | Planned to start | 2 | On place | 1 | I do not know | 2 | On place | 1 | Planned to start | 2 | Planned to start | 2 | On place | 1 |
| Niibi | On place | 1 | On place | 1 | On place | 1 | On place | 1 | On place | 1 | On place | 1 | On place | 1 |
| Perstorp | On place | 1 | On place | 1 | Not doing | 2 | Not doing | 2 | On place | 1 | On place | 1 | On place | 1 |
| Eurajoki Fertilizer | On place | 1 | On place | 1 | Planned to start | 2 | Planned to start | 2 | Planned to start | 2 | Planned to start | 2 | Planned to start | 2 |
| Eurajoki Substrate | On place | 1 | On place | 1 | Planned to start | 2 | Planned to start | 2 | On place | 1 | Planned to start | 2 | On place | 1 |
| Mosås | On place | 1 | On place | 1 | On place | 1 | On place | 1 | On place | 1 | On place | 1 | On place | 1 |
| Grubbenvorst | On place | 1 | Planned to start | 2 | Planned to start | 2 | Planned to start | 2 | On place | 1 | Planned to start | 2 | On place | 1 |
| Nurmijärvi Biorefining | On place | 1 | On place | 1 | On place | 1 | Not doing | 2 | On place | 1 | On place | 1 | Not doing | 2 |
| Joutseno Biorefining | On place | 1 | On place | 1 | On place | 1 | Planned to start | 2 | On place | 1 | On place | 1 | Planned to start | 2 |
| De Lier | Planned to start | 2 | On place | 1 | Not doing | 2 | Not doing | 2 | On place | 1 | Not doing | 2 | Not doing | 2 |
| Drachten | On place | 1 | Planned to start | 2 | I do not know | 2 | Planned to start | 2 | Planned to start | 2 | On place | 1 | Planned to start | 2 |
| Hardenberg | Not doing | 2 | Not doing | 2 | Not doing | 2 | Not doing | 2 | On place | 1 | On place | 1 | On place | 1 |
| Wijchen | Planned to start | 2 | Not doing | 2 | Not doing | 2 | Not doing | 2 | Not doing | 2 | Not doing | 2 | Not doing | 2 |
| | On Place | 69 % | On Place | 69 % | On Place | 31 % | On Place | 23 % | On Place | 69 % | On Place | 54 % | On Place | 54 % |
| | Planned to start | 23 % | Planned to start | 15 % | Planned to start | 23 % | Planned to start | 38 % | Planned to start | 23 % | Planned to start | 31 % | Planned to start | 23 % |
| | Not doing | 8 % | Not doing | 15 % | Not doing | 31 % | Not doing | 38 % | Not doing | 8 % | Not doing | 15 % | Not doing | 23 % |
| | I do not know | 0 % | I do not know | 0 % | I do not know | 15 % | I do not know | 0 % | I do not know | 0 % | I do not know | 0 % | I do not know | 0 % |
| | | 1 | | 1 | | 2 | | 2 | | 1 | | 1 | | 1 |

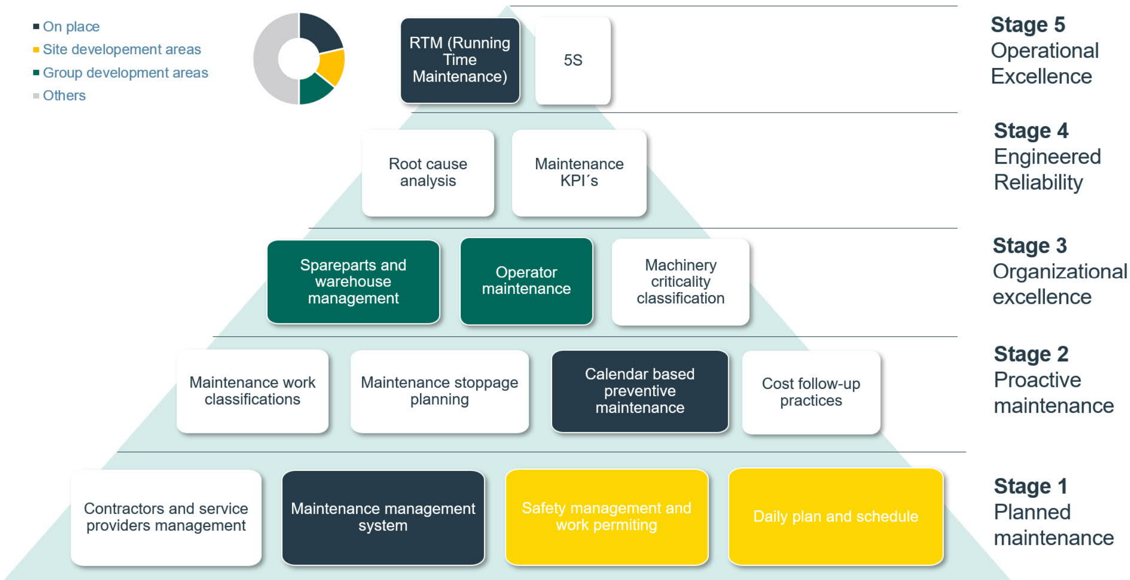
| 33. Area of operation: Day-to-day management - Spareparts and warehouse management | moodi | 37. Area of operation: Day-to-day management - Contractors and service providers management | moodi | 38. Area of operation: Day-to-day management - Maintenance stoppage planning | moodi | 40. Area of operation: Total Productive Maintenance (TPM) practices - Root cause analysis | moodi | 44. Area of operation: Total Productive Maintenance (TPM) practices - RTM (Running Time Maintenance) | moodi | 45. Area of operation: Total Productive Maintenance (TPM) practices - 5S (Sort, Set in order, Shine, Standardize, Sustain) | moodi | 47. Area of operation: Total Productive Maintenance (TPM) practices - Safety management and work permitting | moodi |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Not doing | 2 | Not doing | 2 | On place | 1 | Not doing | 2 | I do not know | 2 | On place | 1 | On place | 1 |
| On place | 1 | On place | 1 | On place | 1 | On place | 1 | On place | 1 | Not doing | 2 | On place | 1 |
| On place | 1 | On place | 1 | On place | 1 | On place | 1 | On place | 1 | On place | 1 | On place | 1 |
| Planned to start | 2 | On place | 1 | On place | 1 | Not doing | 2 | Planned to start | 2 | On place | 1 | On place | 1 |
| Planned to start | 2 | On place | 1 | On place | 1 | Not doing | 2 | Planned to start | 2 | On place | 1 | On place | 1 |
| On place | 1 | On place | 1 | On place | 1 | Planned to start | 2 | Planned to start | 2 | On place | 1 | On place | 1 |
| Planned to start | 2 | On place | 1 | Planned to start | 2 | Planned to start | 2 | Planned to start | 2 | Planned to start | 2 | Planned to start | 2 |
| On place | 1 | Planned to start | 2 | On place | 1 | Planned to start | 2 | Not doing | 2 | On place | 1 | On place | 1 |
| Planned to start | 2 | On place | 1 | On place | 1 | Planned to start | 2 | On place | 1 | I do not know | 2 | On place | 1 |
| Not doing | 2 | Not doing | 2 | Not doing | 2 | Not doing | 2 | Not doing | 2 | Not doing | 2 | Not doing | 2 |
| On place | 1 | On place | 1 | On place | 1 | On place | 1 | I do not know | 2 | On place | 1 | On place | 1 |
| Not doing | 2 | Not doing | 2 | Not doing | 2 | Not doing | 2 | Not doing | 2 | Not doing | 2 | Not doing | 2 |
| Not doing | 2 | Not doing | 2 | Not doing | 2 | Not doing | 2 | Not doing | 2 | Not doing | 2 | Not doing | 2 |
| On Place | 38 % | On Place | 62 % | On Place | 69 % | On Place | 23 % | On Place | 23 % | On Place | 54 % | On Place | 69 % |
| Planned to start | 31 % | Planned to start | 8 % | Planned to start | 8 % | Planned to start | 31 % | Planned to start | 31 % | Planned to start | 8 % | Planned to start | 8 % |
| Not doing | 31 % | Not doing | 31 % | Not doing | 23 % | Not doing | 46 % | Not doing | 31 % | Not doing | 31 % | Not doing | 23 % |
| I do not know | 0 % | I do not know | 0 % | I do not know | 0 % | I do not know | 0 % | I do not know | 15 % | I do not know | 8 % | I do not know | 0 % |
| | 2 | | 1 | | 1 | | 2 | | 2 | | 1 | | 1 |

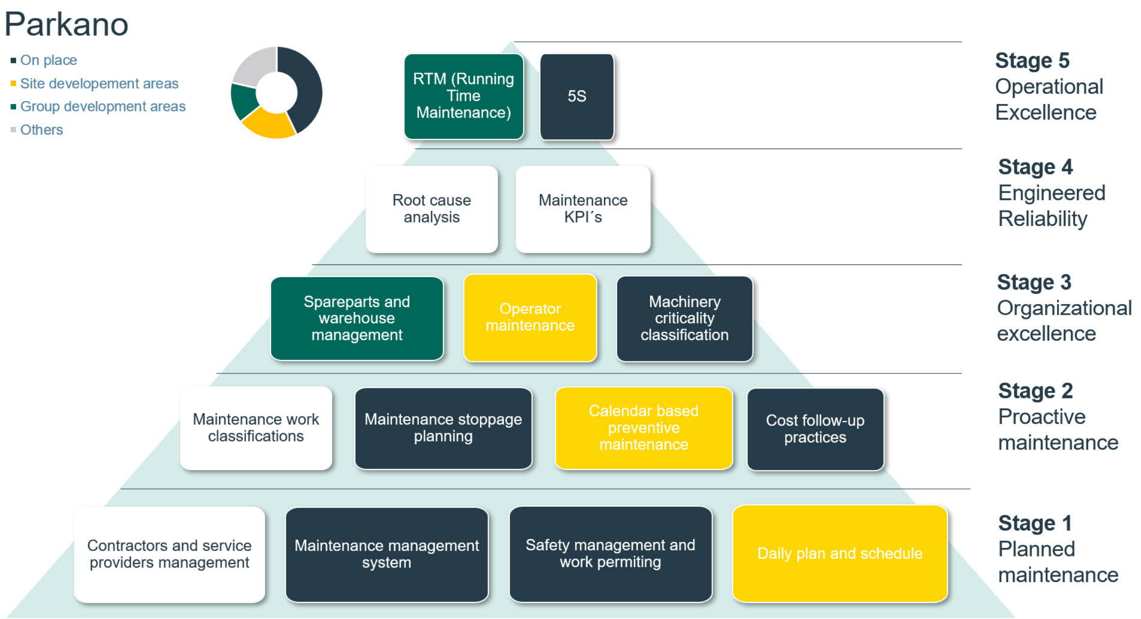
## The site specific maintenance frameworks

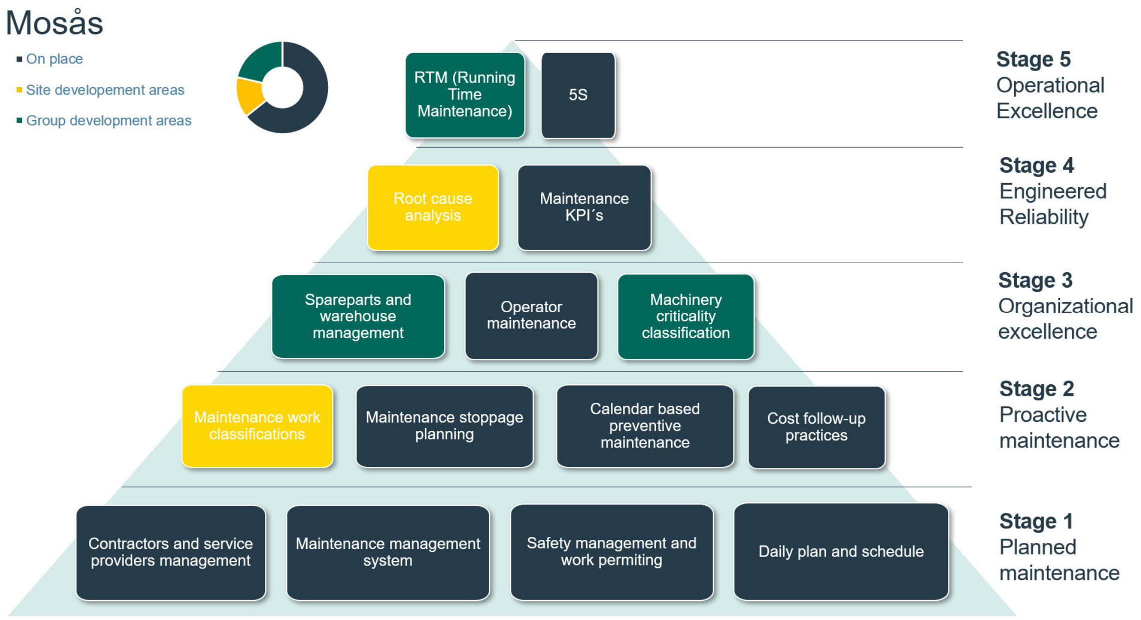
### Eurajoki Site (Substrate and Fertilizer factory)




### De Lier




Parkano
On place
Site developement areas
Group development areas
Others
RTM (Running Time Maintenance)
5S
Root cause analysis
Maintenance KPI´s
Spareparts and warehouse management
Operator maintenance
Machinery criticality classification
Maintenance work classifications
Maintenance stoppage planning
Calendar based preventive maintenance
Cost follow-up practices
Contractors and service providers management
Maintenance management system
Safety management and work permiting
Daily plan and schedule
Stage 5 Operational Excellence
Stage 4 Engineered Reliability
Stage 3 Organizational excellence
Stage 2 Proactive maintenance
Stage 1 Planned maintenance


Mosås
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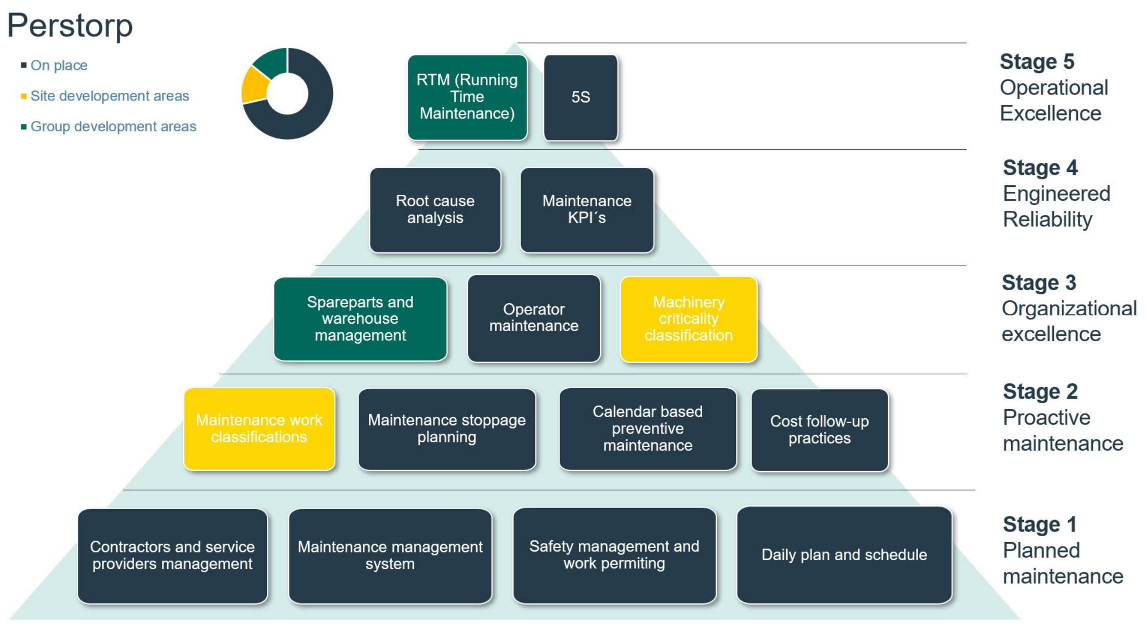
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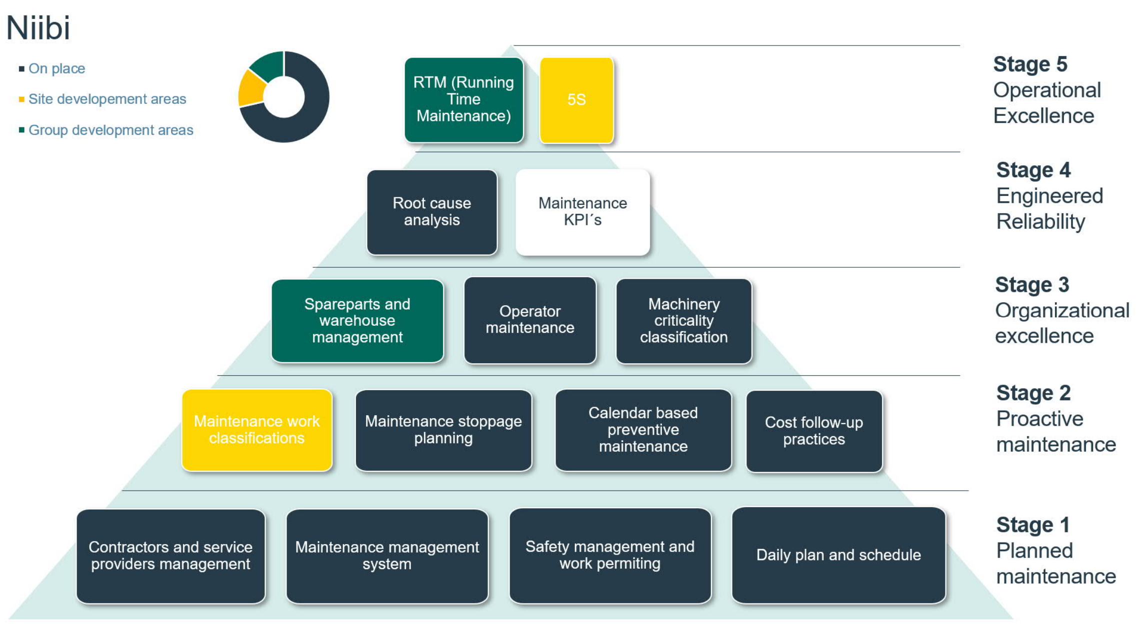
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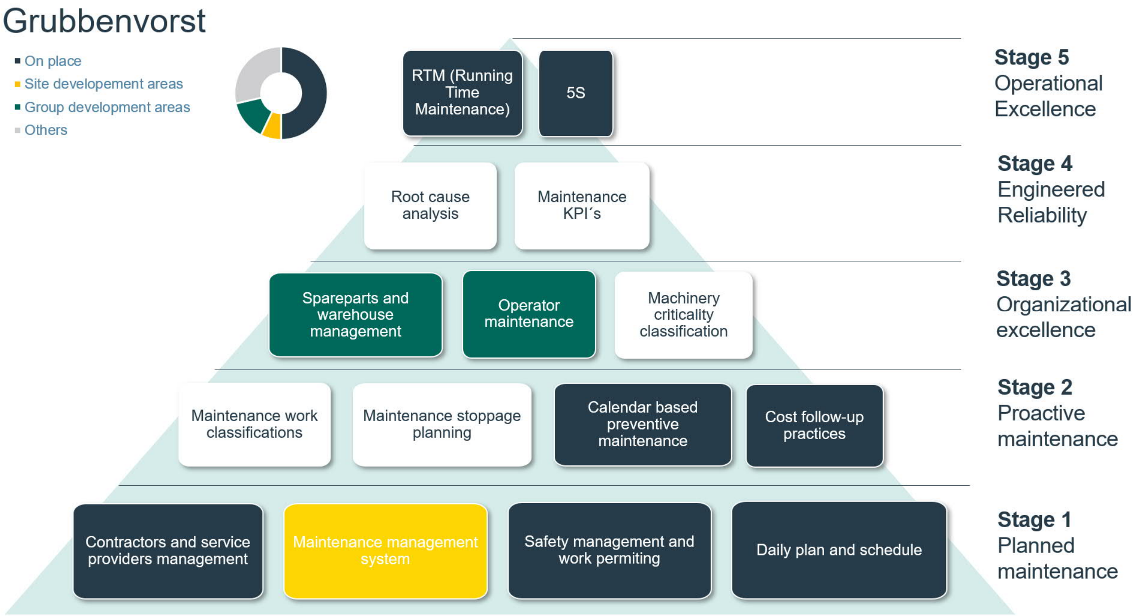
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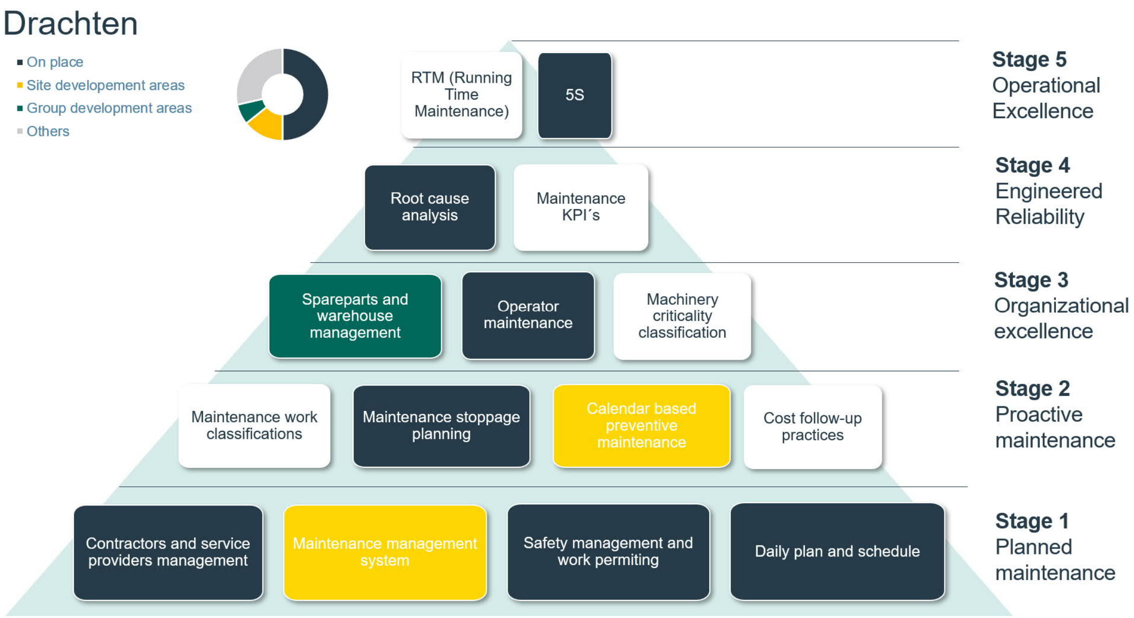
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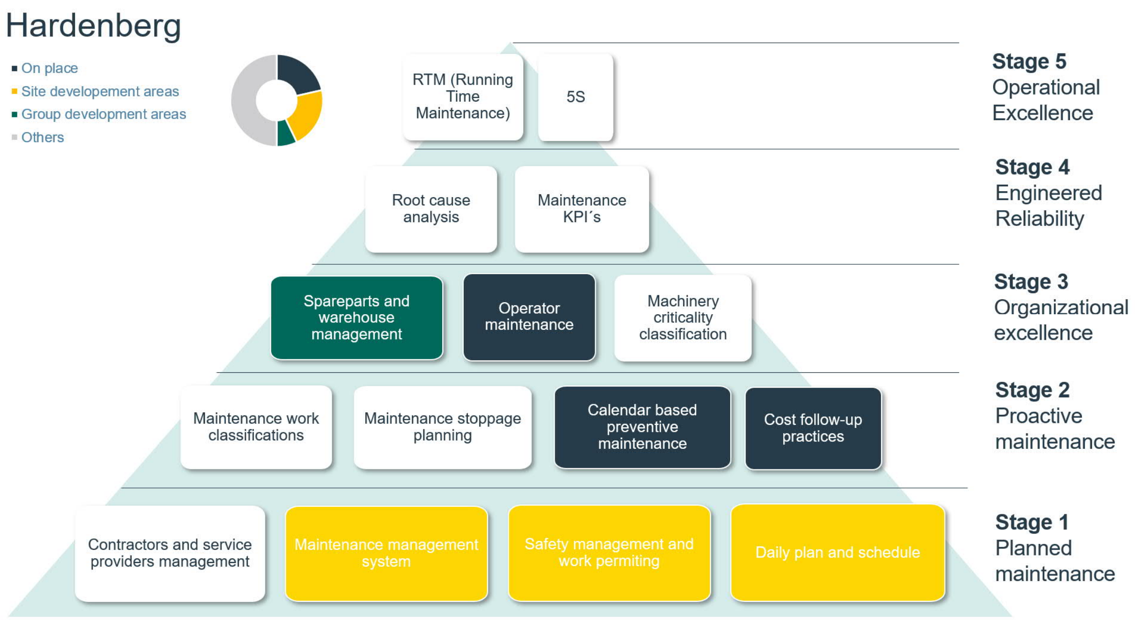
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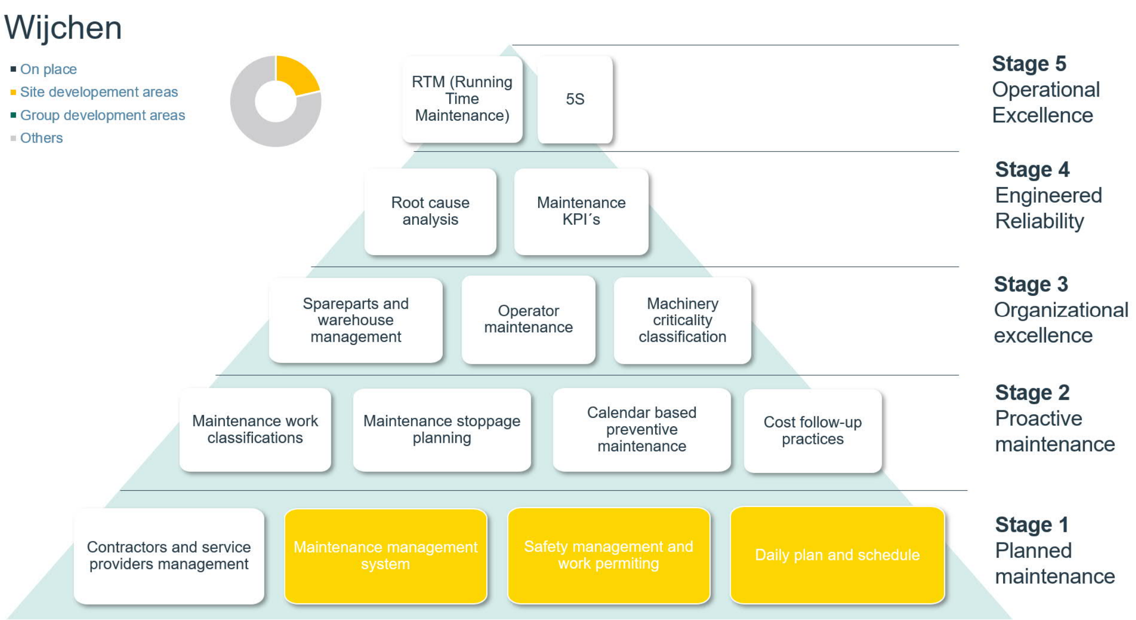
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