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Electronic Components and Systems for European Leadership

Cyber Physical System based Proactive Collaborative Maintenance

D1.2 Consolidated State-of-the-Art of Sensor-based Proactive Maintenance Appendix 19: Different stakeholders and value chains involved in PMM

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Abstract

This document focuses on the different stakeholders and value chains involved in proactive monitoring and maintenance (PMM). This appendix offer an overview of internal and external stakeholders and value chains in overall maintenance process in process industry. To achieve high availability, reliability and quality of production processes, each phase of the overall maintenance process has to work internally and seamlessly in conjunction with the other phases. Maintenance process is highly dependent on external stakeholders. Good information flow and knowledge exchange are extremely important in overall maintenance process and it involves everyone. Seamless collaboration between different stakeholders (internal and external) and manufacturing company is essential to achieve competitive advantage in global competitive arena.

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1 Introduction

This paper focuses on the "Different stakeholders and value chains involved in PMM". It handles the roles of the stakeholder and value chains of proactive monitoring and maintenance (PMM) in manufacturing industry. In maintenance PMM practices are important to manufacturer because it ensures the plant functions availability, reliability, product quality, cost efficiency and maintenance cost effectiveness and the efficient use of resources. [1] [2] Maintenance can have a great impact on the capacity for production and quality on produced products [3]. Manufacturers can maintain and ensure their competitive advantage in global competitive arena with different maintenance practices. Globalization and harsh competition increase the requirements of manufacturer to improve their processes and productivity and the same time reduce costs.

According to Finnish standards association SFS-EN 13306 maintenance is defined as the combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function" [4] Maintenance operates in parallel with production [3] and supports production ensuring its error free running. Maintenance activities are considered as a support functions/activities in a manufacturing company [5] and its value doesn't show to the customers. The fundamental objectives of the maintenance are production overall equipment effectiveness (OEE) and good dependability which consists of reliability performance, maintainability and maintenance supportability. If these are properly managed they create basis for the good availability and utilisation rate. [6] Proactive monitoring and maintenance belongs to planned maintenance and there preventive maintenance activities [7] and aim of these activities is failure detection of devices and machines before breakdown or probability of unexpected equipment failure [8]. Proactive and preventive maintenance activities are usually undertaken a certain calendar based period of time.

2 Different value chains in the PMM

According to Walters and Rainbird (2007) the value chain approach offers a model which includes both customer and corporate expectations. It offers a means to start strategic and operational analysis of an opportunity at a macro (process) level and at a micro (activity) level. Value chain model consists of a process based perspective of the organization, and has dimensions not only intraorganizational but also interorganizational and often intercontinental. Value chain analysis classify the core processes and core capabilities involved in meeting the essential corporate and customer value drivers. Value drivers can be defined to create competitive advantage for organization. [9] Value chain analysis play a key role in understanding the core competitiveness of an enterprise. From the value flow of the production chain certain activities have to be identified. These activities can be separated to the value adding activities and not-value added ones. The value adding activities are also known as critical success factors (CSFs) [5].

Fundamental basis to the value chain thinking is in a Michael Porter's concept, which he developed in the middle of the eighties. Elements of the Porter's value chain framework (figure 1.) includes company primary activities like: inbound logistics, operations, outbound logistics, marketing & sales and service. The primary activities have supporting activities like: firm infrastructure, human resource management, technology development and procurement. [10] The Porter's framework describes how the organization performs and tie them to the organizations competitive environment. [11] Operations are primary activities of the value chain and those operations range from input changing to a final product. These can be machines, packaging, assembly, maintenance of equipment, checking and other factory service functions. [10] Proactive monitoring and maintenance (PMM) are methods and parts of the operations, which belong to the primary activities of the firm in Porter's value chain model. This report will focus to examine the value chain process especially from operations point of view.

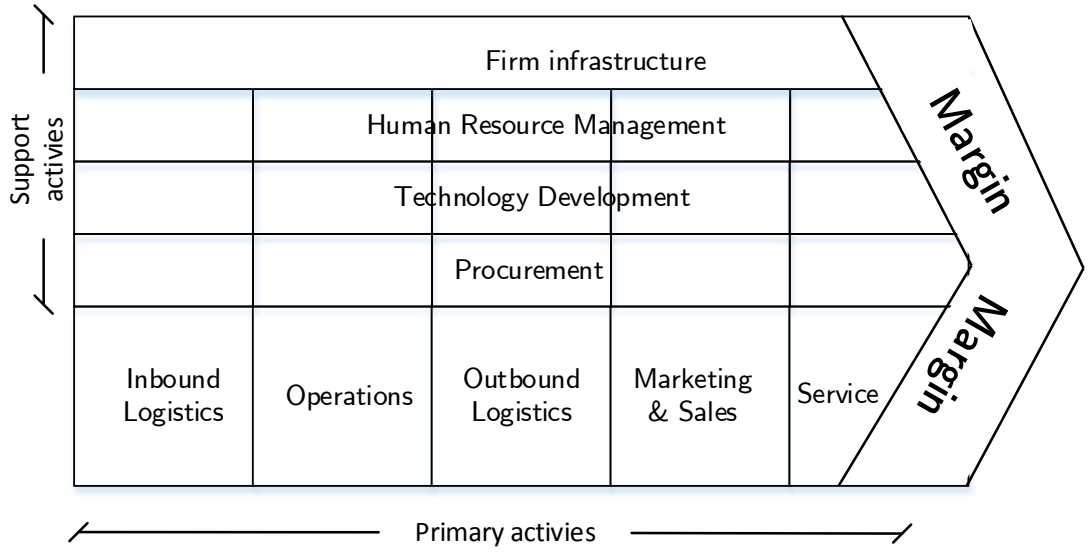

Figure 1. Elements of Porter's value chain [18]

2.1 Maintenance process

Sub-processes of an overall maintenance process can be seen in figure 2. Maintenance process involve sub-processes like management, support planning, preparation, executions, assessment and improvement. These sub-processes include different sets of activities which are interrelated and adapted to fulfil requirements from different stakeholders. Different stakeholder perform different tasks in sub-process. [12] In Figure 2 the completion of work cycle is vital to effective work execution that required equipment condition and performance is attained [2]. Every organization usually tailor its processes based on customer needs and the context in which maintenance and maintenance support is being applied. [13]

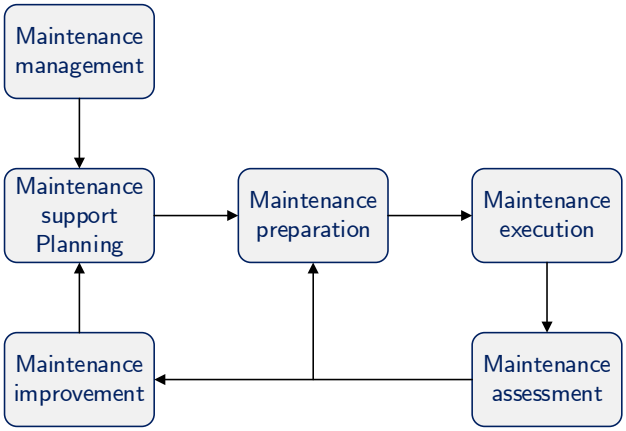

Figure 2. Sub-processes of an overall maintenance process **[13]**

2.1.1 Maintenance management

In figure 2, the first phase of overall maintenance process starts from the management of maintenance and maintenance support activities. These activities consists of developing and updating maintenance policy, providing finances for maintenance and finally coordination and supervision of maintenance. The Maintenance policy is developed with the management responsible for maintenance and maintenance support in conjunction with all groups who involved in maintenance. These are usually documented formally and updated regularly. Sufficient financial support is usually provided and supported by budgeting methods and financial reporting. Organizational structures are usually designed to enable maintenance and maintenance support activities and deal effectively with groups that provide maintenance resources both internally and externally. [13]

2.1.2 Maintenance support planning

In figure 2, the second phase of overall maintenance process continues with support planning which consist of maintenance support definition, maintenance task identification, maintenance task analysis and maintenance support resources. The maintenance support planning phase must be establish the maintenance concept for items requiring maintenance, providing the necessary maintenance resources and to ensuring that information is collected during maintenance. [13]

2.1.3 Maintenance preparation

In figure 2, at the third phase of overall maintenance process continues with maintenance preparation which consist of planning maintenance tasks, scheduling activities and assigning and obtaining

resources. Planning specific maintenance task needs enough time to plan and supply the necessary resources. Important task and activities are planned according to priority system and ensured that most acute and important tasks are carried out first and resources utilized effectively. [13]

2.1.4 Maintenance execution

In figure 2, the fourth phase of overall maintenance process, the process flow continues with maintenance execution which consist of performance of maintenance, recording results, special safety and environmental procedures. Maintenance tasks are usually performed with care and attention to the technical aspects. Preventive maintenance may consist of the following things: [13]

- gathering technical data and description;
- obtaining spare parts and tools and support equipment;
- travelling to the worksite;
- preparation of the worksite such as equipment shutdown, isolating and lockout procedures;
- active maintenance time;
- observations and measurement;
- testing and checkout;
- clearing the worksite;
- recording necessary information. [13]

2.1.5 Maintenance assessment

In figure 2, the fifth phase of overall maintenance process, the process flow continues with maintenance assessment with measurement of maintenance performance, analysis of results and assessment of actions to be taken. Maintenance assessment of preventive maintenance task can be performed either each time maintenance is performed or in certain period of time basis to review overall performance. When analyzing the results the organizations usually use standard and repeatable method for collecting and analyzing data and interpreting results. The review usually cover the effectiveness of maintenance, technical aspects of the maintenance task, adequate of resources and operating, safety and environmental aspects. [13]

2.1.6 Maintenance improvement

In figure 2, the sixth phase of overall maintenance process, the process flow continues with maintenance improvement which consist of improving the maintenance concept, improving resources, improving procedures and modifying equipment. Maintenance improvement can be achieved by management support, effective processes, and communication. A validation process may be needed to ensure the appropriate preventive action has been taken and improvement has achieved. [13]

3 Different stakeholders in the PMM

The literature discusses a broad range of definitions on the stakeholder concept. Freeman's (2010) definition of "stakeholder" is "any group of individual who can affect or is affected by the achievement of an organization's purpose" [14]. In table 1 is presented couple of definitions of term stakeholder from different authors.

Table 1. A sample of definitions of stakeholder including following variants

Authors	Definition
Nutt and Backoff 1992:439 [15]	*'…all parties who will be affected by or will affect the priority strategy'.*
Bryson 1995:27 [16]	*'Any person, group, or organization that can place a claim on an organization's attention, resources, or output, or is affected by that output'.*
Johnson and Scholes 2002:206 [17]	*'…those individuals or groups who depend on the organization to fulfil their own goals and on whom, in turn, the organization depends'.*
Walker, Bourne and Rowlinson 2007:73 [18]	*'Stakeholders are individuals or groups who have an interest or some aspect of rights or ownership in the project, and can contribute to, or be impacted by, either the work or the outcomes of the project.'*

Maintenance is a big expense in manufacturing business and it has high impact on the company's costs right after costs of capital and raw material costs [19] In Finland the average maintenance related costs in manufacturing industry are estimated to be 5.5 percent of company turnover, but they can rise even to twenty five percent of company turn over [20]. Hansen (2006) study points out that the biggest portion of maintenance cost come from labour and materials used on major jobs [21]. In their study Pophaley and Vyat (2010) pointed out that next to the energy costs maintenance costs are largest part of any operational budget [3]. Proactive monitoring techniques increase the reliability of equipment and makes the production process more predictable [22]. Proactive and predictive maintenance techniques work together to maximize asset lifetime [23]. However maintenance is tended to view as a cost of doing business, or a "necessary evil" [24] in production plant. Production plant needs different stakeholders to keep machines running. Every person has their own role which creates value in to the whole value chain. Different stakeholders which are key players in the proactive monitoring and maintenance are presented in section 2.1 internal stakeholders and 2.2 external stakeholders. In this next section report will focus to examine the stakeholders especially from operations point of view.

3.1 Internal stakeholders

Internal stakeholder activities / tasks are part of the operations and therefore those are a part of the company's primary activities in Porter's value chain. According to Porter (1985, 58) operations of the value chain are functions which are associated with changing the inputs to the final product. This includes for example machining, packaging, assembly, equipment maintenance, inspection and other factory service functions. [10]

In this section is presented the main contributors and internal operative stakeholders in the sub-processes of an overall maintenance process of the organization. These internal stakeholders are main actors in PMM, which operate usually inside the organization and work there on a daily basis. The tasks are part of the maintenance process which are presented in table 4. Stakeholders and tasks are collected in the same table. However, the table is not an all-inclusive list about maintenance tasks in the maintenance process.

3.1.1 Maintenance manager

In maintenance management phase maintenance manager task is to collaborate with other internal and external stakeholders. Networking and collaboration with all stakeholders are very important in modern industry. Important tasks of the maintenance management are e.g. formulation of maintenance strategy / operation and maintenance strategy together with operators and maintenance personnel. Other tasks are budgeting, different kind of contracts, specifications to OEM manufacturing and determining of KPI's (Key Performance Indicators). Maintenance support planning phase maintenance manager tasks are e.g. maintenance scheduling and planning of production shutdown. Maintenance assessment phase maintenance manager tasks are e.g. reporting to the upper management, process or maintenance improvements, supervising realisation of the strategy and performance monitoring. Maintenance improvement phase maintenance manager tasks are maintenance planning, manufacturing and process improvements and giving orders to the maintenance supervisor / foreman.

3.1.2 Maintenance supervisor / foreman

Maintenance supervisor is responsible for leading daily production process along with operations supervisor. Operations supervisor monitors the work of the operators and is responsible for production process of manufacturer plant. Maintenance supervisor / foreman provides information on preventive maintenance and condition monitoring to the maintenance manager. Supervisors /foreman are in the middle of the information flow so they catch the horizontal and vertical information flow. Information is usually tacit knowledge, which is hard to explain or express in words. Therefore computerized maintenance management systems (CMMS) play a key role to catch the tacit knowledge of the maintenance personnel.

Maintenance supervisor / foreman tasks in maintenance support planning phase of an overall maintenance process are e.g. work orders, resource allocation and planning of production shutdown to CMMS. Maintenance preparation phase tasks are checking of spare parts and doing work instructions and manuals. In maintenance assessment phase supervisor is responsible e.g. about reporting and informing to the upper management about departmental issues. In maintenance improvement phase tasks are dealing with manufacturing / process improvements with maintenance and operators teams. Maintenance supervisor tasks in the maintenance improvement phase are repetitive fault elimination and reliable information to determine the cause of damage and to solve problems.

3.1.3 Work planner

Work planner tasks are resource and spare parts allocation to CMMS in the maintenance support planning phase. Tasks are to attach the work instructions / guidelines and needed licences to the racks or the welding work in the maintenance preparation phase. In maintenance assessment phase maintenance work planner tasks are to evaluate previous work plans and update model work plan table in CMSS. In maintenance improvement phase work planner improves the work plan if needed.

3.1.4 Maintenance technician and condition monitoring expert

Maintenance is usually divided into electrical and mechanical tasks. It depends on the type of process equipment breakage, to whom the process operators call first. The operator can also make service request to CMMS. Proactive maintenance and proactive condition monitoring plans are calendar based activities. Those plans are usually based on Failure Mode and Effects Analysis (FMEA) or its extension Failure Mode, Effects and Criticality Analysis (FMECA) and also root cause failure analysis. Maintenance technician and/or condition monitoring expert print the preventive maintenance plan or condition monitoring plan and to perform the tasks of the plan.

In maintenance preparation phase the tasks are usually: assessment of work order, checking equipment breakdown /service order history (knowledge of equipment), conducting failure analysis, planning preventive maintenance, checking the equipment history (tacit knowledge + CMMS), estimating the remaining useful life of the equipment / machine, doing root cause failure analysis, formulating and reading work instructions and manuals, collecting tools and spare parts from warehouse, task and environment preparation and wearing personal safety equipment.

In the maintenance execution phase the maintenance technician do fault diagnostics, examine and repair the equipment fault, do proactive maintenance tasks with different diagnostics, do condition monitoring tasks, measure vibration / vibration analysis, do temperature measurement and do lubrication / lubricant analysis and also thermal imaging of the target. In the maintenance assessment phase maintenance technician or condition monitoring expert does the documentation to the CMMS. In the maintenance improvement phase maintenance technician and condition monitoring expert do maintenance planning, manufacturing planning and process improvements together with project group.

According to Dunn the traditional condition monitoring is performed inside the organization using its own personnel. To the process plant it will be economical and strategic important to perform usual, routine condition monitoring tasks in-house, rather than contract these services to the outside service providers. [25]

3.1.5 Process operator

Process operators' main job is to control and adjust the production with process automation system. Process operators are increasingly taking part to the operations and maintenance tasks like condition monitoring operator rounds and proactive monitoring and maintenance. Their tasks has been transferring more and more to operation & maintenance tasks than e.g. ten years ago. For example in forest industry process plant operators does maintenance tasks e.g. preventive maintenance jobs and

operator rounds. Some process plants maintenance department is outsourced and operators have to do PMM tasks along with their own duties.

Nowadays process operator tasks are e.g. in a corrective maintenance tightening of flange, changing the filtration and fixing the small faults. Usually they call the maintenance service. In proactive maintenance tasks are e.g. nozzle changing work, measurements, monitoring and measurement of devices. In the operator round they do condition monitoring with human senses; hearing, feeling/touching, seeing and smelling. [26]

In the maintenance process operators do mainly maintenance preparation and conduct failure analysis. They have extensive amount of knowledge about equipment histories (tacit knowledge) because they work close to the process machine. Operators can do work instructions and manuals, collect tools and spare parts for the work, prepare working environment before they or maintenance technician starts to work.

The operators usually notice and examine the equipment fault in the process and inform maintenance technician or production / maintenance supervisor in maintenance execution phase. The operators tasks are e.g. condition monitoring; vibration measurement with vibration pen in their operator rounds. Operator report to the CMMS in the maintenance assessment phase. Sometimes operators take part in meetings as an expert, where the project group do a planning for manufacturing and a process improvements.

3.1.6 It-advisory and support

It-advisory and support keep up the master data of CMMS and other maintenance related systems in maintenance support planning phase of maintenance process. In maintenance assessment phase they evaluate programmable logic systems and process automation systems. They also make adjustments to the process automation system in that phase. It-advisory and support tasks are to program the process logic and the process controlling systems in maintenance improvement phase.

3.2 External stakeholders

The external stakeholders are equipment manufacturer, spare parts manufacturer, maintenance service provider, material supplier, maintenance system manufacturer, Original Equipment Manufacturer (OEM), warehousing (suppliers/user reserve stock/standard parts), remote condition monitoring and engineering company. These stakeholder activities / tasks are part of the procurement activities in company's value chain and therefore a part of the support functions. According to Porter (1985, 59) procurement refers to the purchase of inputs used in company's value chain. Those purchasable inputs are raw materials, supplies and other consumable items, as well as assets like equipment, laboratory equipment, office furniture and buildings. Although purchased inputs commonly associated with the basic activities, they include every value of the function, also to support functions. [10].

In this chapter are presented external stakeholders tasks who are involved in the certain phase of the maintenance process. The tasks are part of the maintenance process and a summary of these actions are presented in table 5. Every stakeholder take part in the maintenance process and give their own input to that PMM process which benefits the manufacturer.

3.2.1 Equipment manufacturer

Equipment manufacturer has equipment aftersales service and those services may contain maintenance, training, warranty and both financing and legal issues which they offer to the customer. In maintenance support planning phase the equipment / device manufacturer deliver the equipment to the industrial organization. The manufacturer is an expert of their own equipment in condition monitoring and maintenance and they know the equipment best maintenance intervals. Manufacturer offer also a work instructions and manuals in the maintenance preparation phase. Maintenance execution phase they offer support around the clock, sometimes continuous remote monitoring as a service e.g. ABB; maintenance of their motors (may also act as a maintenance service provider).

3.2.2 Spare parts manufacturer

The spare parts manufacturer task in the maintenance management phase is e.g. to ensure the availability of the spare parts. They offer also information about warranty swapping and the new products to the manufacturer. In support planning phase they offer standard parts and substitutive equivalent parts if needed.

3.2.3 Maintenance service provider (outsourced maintenance / partly outsourced maintenance)

The maintenance service providers are either completely outsourced maintenance or partly outsourced maintenance. The maintenance service provider does resource allocation to the suitable job or project together with customer. The Service provider offers skilled labor and expertise to the customer in the maintenance management phase. According to Al-Mutairi and Al-Hammad (2015, 8) the most outsourced maintenance type in manufacturing industries are corrective and scheduled maintenance and also the production shutdown [27].

Maintenance service provider task in maintenance preparation phase is to take part in customer work and to support customer own labor e.g. maintenance technician in their work at production shutdown.

Shutdown needs a huge amount of manpower. In-house personnel are not always sufficient enough to cover that need. [27] The maintenance service provider personnel work the same way as a maintenance technician and they do also process improvement work at the maintenance execution phase. They do also maintenance improvement work by proposing manufacturing and process improvements to the upper management.

Outsourced maintenance technician work a part of the production shutdown and process improvement task. Outsourced services of maintenance are e.g.: installation service, design work, measurements, washes, conveyor services, dust removal, corrective maintenance, condition monitoring, preventive maintenance work, projects (construction), replacement of wear parts, pipe and tubing replacement work as well as special measurements.

3.2.4 Material supplier

Material suppliers task in maintenance support planning phase are e.g. to offer the right material to the right target. They offer also alternative materials if needed and give expertise to the customer about use of material. Maintenance preparation consists of assigning and obtaining resources. Customer have a need to get a different material e.g. to production shutdown and to the maintenance work.

3.2.5 Maintenance system manufacturer; Business software solutions (i.e. ERP or CMMS)

Maintenance system manufacturer or enterprise system manufacturer together define what kind of input data is loaded to the system in maintenance management phase. The file structure and the blue print of the whole systems has to be defined properly with company's maintenance personnel. CMMS give the manager control over the maintenance of all facilities and maintainable equipment from acquisition to disposal. According to SFS-EN 60300-3-14:en maintenance information system contains information including following (see table 2):

Table 2. Containing of maintenance information system SFS-EN 60300-3-14 [13]

CMMS include:

item description and location data;
preventive and corrective maintenance task description;
history of preventive and corrective maintenance;
reporting of failures and defects, including the operating condition when the failure is discovered;
modifications applied to items;
materials and spare parts information;
work planned and scheduled for execution;
condition monitoring data;
economic and maintenance performance data;
information and advice on maintenance due to new knowledge or experience;
service bulletin issued by manufacturers.

The maintenance support planning phase must ensure that information is collected during maintenance. The input data (file structure, blue print) usually have properly installed in the CMMS. Also connections to other systems and / or integration with other systems not only provide and ensure information and knowledge transfer between machines but also with machine to humans. CMMS manufacturer provide also expertise to the customer e.g. in the form of updates and personnel training.

In the maintenance process assessment phase a maintenance system manufacturer usually plan together with a customer the development needs related to ERP or CMMS. Some process plant manufacturers have e.g. (semi-) automatic generation of spare part orders from the CMMS or ERP-system. It's directly pointed to the suppliers' ERP-system in the real time order processing. Maintenance improvement phase maintenance system manufacturer task is to execute the customer (enterprise) development needs related to ERP or CMMS.

3.2.6 Original Equipment Manufacturer (OEM)

The maintenance management phase OEM manufacturer task is to offer after sales services which includes maintenance, training, warranty and financing issues. These include the legal issues. In the maintenance support planning phase OEM manufacturer task is to deliver equipment, give information about equipment maintenance intervals and also the expertise to the customer

3.2.7 Warehousing (suppliers/user reserve stock/standard parts)

The manufacturing plant can have their own warehouse department from where the personnel can deliver spare parts and materials to all over the plant. One solution is for the manufacturer to outsource

its warehouse activities or use e.g. consignment stock. Consignment stock is the stock of goods at an external customer's site that is still the property of the supplier [28]. Manufacturer can hold such goods as e.g. standard parts in their own warehouse. Manufacturer do not necessarily need to hold all spare parts and materials at their own stock, because it costs a lot. One option is that suppliers of spare parts and materials can hold goods in their own warehouse. Manufacturer can order goods when they are needed.

In the maintenance management phase the company's procurement must make contracts with spare part and material suppliers and agree with delivery times. Maintenance support planning phase reliability and availability of spare parts and materials have to be properly planned. In the maintenance preparation phase warehouse personnel collect and deliver needed spare parts, materials and tools to e.g. the maintenance technician or to the manufacturing line. In the maintenance assessment phase warehouse personnel tasks is to follow spare part and tool consumption. They have to keep track on the stock control (inventory control). In maintenance improvement phase the warehouse personnel have to optimize the spare part and tool amounts as a result of consumption.

3.2.8 Remote condition monitoring

Equipment manufacturer and maintenance service providers can offer remote monitoring services on contract based. They can provide a direct network connection to equipment and machines for remote monitoring and control. Equipment manufacturer can remote monitor and control their own devices and service provider can remote monitor and control many device groups which they have agreed with manufacturer.

In the maintenance support planning phase equipment manufacturer and maintenance service providers adjust their condition monitoring programs and define remotely sensing devices / equipment. In maintenance preparation phase their tasks are to analyse device / equipment history and conduct failure analysis. In maintenance execution phase they can do measurement or adjustment of the device or equipment. In maintenance improvement phase their task is to report to the customer CMSS. In the maintenance assessment phase the task is to make an improvement planning for remote monitoring system.

3.2.9 Engineering company

The engineering companies usually do project based planning for plant enlargement phase, process improvement or expansion planning. The engineering company task is to do project contract from project with manufacturing company in the maintenance management phase. Engineering company's task is to do e.g. manufacturing line improvement and process improvement planning. The main task is to give expertise to the customer in a maintenance support planning phase. Engineering company's task is to report to the maintenance manager and to CMMS about changes that have been made. This is task in the maintenance assessment phase.

4 Summary of maintenance process and its stakeholders

Overall maintenance process is a basis for the value chain process (see figure 2). Specific PMM related activities which create value to the maintenance process and stakeholders are presented in table 4 and table 5.

Table 3. Maintenance process with internal stakeholders

		Maintenance Management	Maintenance support planning	Maintenance preparation	Maintenance execution	Maintenance assessment	Maintenance improvement
Internal stakeholders	**Maintenance manager**	*Networking with internal and external stakeholders *Maintenance strategy *Operation and maintenance strategy with operators *Budgeting *Contracts *Specifications to OEM manufacturing *KPI's (key performance indicators)	*Maintenance scheduling *Planning of production shutdown	---	---	*Reporting to the upper management *Process or maintenance improvements *Supervise realisation of strategy *Performance monitoring	*Maintenance planning *Manufacturing and process improvements *Give orders to the maintenance supervisor / foreman
	Maintenance supervisor / foreman	---	* Work order * Resource allocation * Planning of production shutdown	* Check spare parts * Work instructions and manuals	---	* Reporting to the upper management	*Manufacturing / process improvements * Repetitive fault elimination *Reliable information to determine the cause of damage and to solve problems
	Work planner	---	*Resource allocation *Spare parts allocation	*Work instructions / guidelines *Licencies (rack, welding work, etc.)	---	*Evaluation of previous work plan and updating model work table in CMMS	Improvement of work plan to CMMS

	Maintenance technician and condition monitoring experts	--------	--------	*Assesment of work order *Checking equipment breakdown/ service order history (knowledge of equipment) *Conduct failure analysis *Planning preventive maintenance *Equipment history (tacit knowledge + CMMS) *Estimating remaining useful life *Root cause failure analysis *Formulating and reading work instructions and manuals *Collecting tools and spare parts *Task and environment preparation *Personal safety equipment	*Examine and repair the equipment fault *Fault diagnostics *proactive maintenance tasks with different diagnostics *condition monitoring tasks *measurements of vibration / vibration analysis *temperature measurement *lubrication / lubricant analysis *thermal imaging	*Reporting to CMSS	*Maintenance planning *Planning manufacturing and process improvements together with project group *process improvement planning
	Operator	--------	--------	*Equipment history (tacit knowledge) *Conduct failure analysis *Work instructions and manuals *Collecting tools and spare parts *Environment preparation *Personal safety equipment	*Examine the equipment fault and inform maintenance technician or production / maintenance supervisor Condition monitoring; *vibration measurement with vibration pen *operator rounds	* Reporting to CMSS	* Planning manufacturing and process improvements together with project group
	It-advisory and support	--------	*Keeping up the master data in CMMS and other maintenance related systems	--------	--------	*Evaluate programmable logic systems and process automation systems *Adjustments of the process automation system	*Programming the process logic system *Programming the process controlling system

Table 4. Maintenance process with external stakeholders

		Maintenance	**Maintenance**	**Maintenance**	**Maintenance**	**Maintenance**	**Maintenance**

		Management	support planning	preparation	execution	assessment	improvement
External stakeholders	**Equipment manufacturer**	*After sales services (maintenance, training, warranty and financing); legal issues	*Equipment delivery *Equipment maintenance interval	*Work instructions and manuals	*Support around the clock *Continuous remote monitoring as a service * e.g. ABB; maintenance of motors (may act also as a maintenance service provider)	--------	----
	Spare parts manufacturer	*Availability of spare parts * Information about * Warranty swapping new products	*Standard parts *Offer substitutive equivalent parts	--------	--------	--------	------
	Maintenance service provider	--------	*Resource allocation to the suitable job or project *Skilled labour *Expertise to the customer	*Take part of customer work and support customer own labour e.g. maintenance technician	*Production shutdown *Work at the same way like maintenance technician *Process improvement work		*Propose manufacturing and process improvements
	Material supplier	--------	*Offer right material to the right target *Offer alternative materials if needed * Expertise to the customer	*Deliver material to production shutdown *Deliver material to maintenance work	-----	-----	-----

	Maintenance system manufacturer; Business software solutions (i.e. ERP or CMMS)	--------	* Input data (file structure, blue print) *Connection to other systems/ *Integration with other systems *Expertise to the customer	-----	--------	*Planning of customer (enterprise) development needs related to ERP or CMMS. - E.g. (Semi-)automatic generation of spare part orders by the CMMS directly injected to the suppliers' ERP-system; real time order processing	*Execution of customer (enterprise) development needs related to ERP or CMMS.
	Original equipment manufacturer (OEM)	*After sales services (maintenance, training, warranty and financing); legal issues	*Equipment delivery *Give information about equipment maintenance interval *Expertise to the customer	-----	-----	-----	----
	Warehousing (suppliers/ user reserve stock/standard parts)	*Contracts *Delivery times	*Reliability of spare parts availability	*Collecting and deliver needed spare part and tools	-----	*Following spare part and tool consumption	*Optimizing spare part and tool amounts
	Remote condition monitoring		*Adjusting condition monitoring program *Remote sensing devices / equipment	*Analyse device / equipment history * Conduct failure analysis	*Do the measurement or adjustment of the device or equipment	*Reporting to CMSS	*Improvement planning to remote monitoring
	Engineering company	*Contracts about project	*Process improvement planning / *Target improvement planning *Expertise to the customer	-----	-----	*Reporting to maintenance manager / CMMS	----

5 Conclusions

The overall maintenance process and activities consists of six different phases: management, support planning, preparation, executions, assessment and improvement. These processes include different sets of activities which are interrelated and adapted to fulfill requirements from different stakeholders both internal and external.

Proactive monitoring and maintenance (PMM) are parts of the maintenance operations which are involved in different stakeholders at different tasks. Plant managers need to organize stakeholder roles of the value chain, work tasks and information routes in the value chain. Those internal stakeholder roles in maintenance are e.g.: maintenance manager, maintenance supervisor / foreman, maintenance technician and condition monitoring experts, operator, It-advisory and support. The main external stakeholders are usually equipment manufacturer, spare parts manufacturer, maintenance service provider, material supplier, maintenance system manufacturer, Original Equipment Manufacturer (OEM), warehousing (suppliers/user reserve stock/standard parts), remote condition monitoring and engineering company.

PMM-process include different kind of stakeholders. Those stakeholders are key resources in the PMM value chain and the key resources are the key activities in the whole model. There are stakeholders which can be found in house (internal stakeholders at table 4) or outside the plant (external stakeholders at table 5). Internal stakeholders are manufacturing plant personnel and external stakeholders are persons or companies which are outside the manufacturing plant which can contribute by adding value to the manufacturing process and there in PMM-process. Regardless of stakeholder's status in the process, every task contributes to adding value. Different contribution add different kinds of value.

To achieve high availability, reliability and quality of production process, each phase of the overall maintenance process has to work internally and seamlessly in conjunction with the other phases. Different phases of the maintenance process require to be supported by different stakeholders. Some stakeholders do more in certain phases and some in the other. Also some stakeholders operate only in certain phase and others in several. It seems that maintenance process is mainly dependent on external stakeholders. This requires seamless collaboration between internal, external stakeholders and between manufacturing company. Good information flow and knowledge exchange are extremely important in this process and it involves everyone. All this points out the necessity of the MANTIS-platform.

6 List of appendixes

Appendix 1. The relevant standards for Appendix 19, WP6 task 6.1 and 6.2.

Appendix 1. The relevant standards for Appendix 19, WP6 task 6.1 and 6.2.

Standard Organization	Number	Title	Publishing Year
PSK	**6201**	**Maintenance. Terms and definitions**	**2011**
PSK	**7501**	**Key performance indicators of maintenance for use in process industry**	**2010**
SFS	**13306**	**Maintenance. Maintenance terminology**	**2010**
SFS	**60300-3-14**	**Dependability management - Part 3-14: Application guide - Maintenance and maintenance support**	**2004**
SFS	15341	Maintenance. Maintenance Key Performance Indicators	2007
DIN	31051	Fundamentals of maintenance. (Grundlagen der Instandhaltung)	2012
ISO	55000	Asset Management Standard: What Maintenance Reliability Professionals Should Expect	2015
BSI	1325	Value Management. Vocabulary. Terms and definitions	2014
BSI	1325-1	Value management, value analysis, functional analysis vocabulary. Value analysis and functional analysis	1997
BSI	13269	Maintenance. Guideline on preparation of maintenance contracts	2006
BSI	13306	Maintenance terminology	2001
BSI	13460	Maintenance. Documentation for maintenance	2009
BSI	15341	Maintenance. Maintenance key performance indicators	2007
BSI	55000	Asset management. Overview, principles and terminology	2014
BSI	55001	Asset management. Management systems. Requirements	2014
BSI	55002	Asset management. Management systems. Guidelines for the application of ISO 55001	2014
UNI	10144	Classification of maintenance services	2006
UNI	10145	Definition of evaluation factors of services maintenance firms	2007
UNI	10146	Criteria to prepare a contract for supplying maintenance finalized services	2007
UNI	10147	Maintenance - Additional terms and definitions to EN 13306	2003
UNI	10148	Maintenance - Management of a maintenance contract	2007
UNI	10224	Maintenance - Process, sub-processes and main activities - Fundamental principles	2007
UNI	10366	Maintenance - Design criteria of maintenance	2007
UNI	10449	Maintenance - Criteria to prepare and to manage the permit to work	2008
UNI	10584	Maintenance. Systems of information of maintenance	1997

UNI	10652	Maintenance - Appraisal and evaluation of the goods condition	2009
UNI	10749-1	Maintenance - Guidelines for management of maintenance materials - General aspects and organizational problems	2003
UNI	10749-2	Maintenance - Guidelines for management of maintenance materials - Criteria for classification, codification, standardization and support	2003
UNI	10749-3	Maintenance – Guide-lines for management of maintenance materials - Criteria for the choice of materials to be managed	2003
UNI	10749-4	Maintenance - Guidelines for management of maintenance materials - Criteria for operational management	2003
UNI	10749-5	Maintenance - Guidelines for management of maintenance materials - Criteria for purchasing, tests and final check	2003
UNI	10749-6	Maintenance - Guidelines for management of maintenance materials - Administration criteria	2003
UNI	10992	Maintenance budget for manufacturers and suppliers of products and services - Guidelines for the definition, approval, management and check	2002
UNI	11063	Maintenance - Definitions of ordinary and extraordinary maintenance	2003
IEC	60300-3-16	Dependability management - Part 3-16: Application guide - Guidelines for specification of maintenance support services	2008
IEC	62550	Spare parts provisioning	2015
TAPPI	10685	Maintenance - Criteria to prepare a maintenance global service	2007
CEN	15628	Maintenance - Qualification of Maintenance personnel	2007
CEN	EN 16646:2014	Maintenance - Maintenance within physical asset management	2014
CENELEC	EN 60300-3-14	Dependability management - Part 3-14: Application guide - Maintenance and maintenance support	2004
CENELEC	EN 60300-3-16	Dependability management - Part 3-16: Application guide - Guidelines for specification of maintenance support services	2008
PSK	7901	Maintenance in industry. Service agreement	2001
PSK	7502	Key performance indicators of logistics. Material function	2002
NF	NF X 60-212	Maintenance - Handbook of instructions maintenance - Definitions and general principles for the wording and layout	1983
NF	NF X60-000	Maintenance function	2002
NF	NF X60-008	Industrial maintenance - Maintenance outsourcing draft guide - Pre-contractual approach	2013
NF	NF X60-100	Maintenance – Preconditions to the maintenance contracts – Inventories and evaluation for the states of items	2007
VDI	2892	Management of maintenance spare parts	2006

VDI	2893	Selection and formation of indicators for maintenance	2006
ISO	*18480-1*	*Facility management — Part 1: Terms and definitions*	*2015*
ISO	*18480-2*	*Facilities Management — Part 2: Guidance on strategic sourcing and the development of agreements*	*2015*
ISO	*37500:2014*	*Guidance on outsourcing*	*2014*
SFS	*EN 13269*	*Maintenance. Guideline on preparation of maintenance contracts*	*2006*
SFS	*EN 15628*	*Maintenance. Qualification of maintenance personnel*	*2014*
SFS	*EN 16646*	*Maintenance. Maintenance within physical asset management*	*2015*

References

[1] U. Kumar, D. Galar, A. Parida, C. Stenström, L. Berges, "Maintenance Performance Metrics: A State of the Art Review," in *MPMM 2011 Maintenance Performance Measurement & Management*, 2011.

[2] P. Muchiri, L. Pintelon, L. Gelders and H. Martin , "Development of maintenance function performance measurement framework and indicators," in *International Journal of Production Economics*, 2010.

[3] M. Pophaley and R. K. Vyas, "Plant maintenance management practices in automobile industries: A retrospective and literature review," in *Journal of Engineering and Management*, 2010.

[4] SFS-EN13306, "Maintenance. Maintenance terminology. 2p.," Finnish Standards Association SFS, 2010, p. 8.

[5] T. Zhang, . Y. Wang and C. Li, "Maintenance Organisazation Value Chain Analysis and Its Formalization," in *Applied Informatics and Communication, Part III: International Conference, ICAIC 2011, Xi'an China, August 20-21, 2011, proceedings, part 3*, 2011.

[6] PSK 6201, *Maintenance. Terms and definitions, 3rd edition,* PSK Standards Association, 2011.

[7] PSK 7501, *Key performance indicators of maintenance for use in process industry. 2nd edition,* Helsinki: PSK Standardisointiyhdistys ry., 2010.

[8] L. Swanson, "Linking maintenance strategies to performance," in *International Journal of Production Economics 70*, 2001.

[9] D. Walters and M. Rainbird, Strategic operations management – A value chain approach, Palmgrave Macmillan, 2007.

[10] M. E. Porter, «Competitive advantage: Creating and sustaining superior performance,, 1985.

[11] D. Recklies, "The Value Chain," 2001. [Online]. Available: http://www.fao.org/fileadmin/user˙upload/fisheries/docs/ValueChain.pdf. [Accessed 7 8 2015].

[12] Olov Candell and Ramin Karim, eMaintenance - Information Driven Maintenance and Support, Division of Operation & Maintenance Engineering, Luleå University of Technology, Luleå, Sweden, 2008.

[13] SFS-EN 60300-3-14:en, *Dependability management, Part 3-14: Application guide; Maintenance and maintenance support (IEC 60300-3-14:2004),* Helsinki, Finland: Finnish Standards Association, 2004.

[14] E. R. Freeman, Strategic management: A Stakeholder Approach, Pitman Series in Business and Public Policy, 2010, p. 292 pages.

[15] P. C. Nutt and R. W. Backoff, Strategic management of public and third sector organizations: a handbook for leaders, San Francisco: Jossey-Bass Publishers, 1992, p. 486.

[16] J. M. Bryson, Strategic planning for public and nonprofit organizations: a Guide to Strengthening and Sustaining Organizational Achievement, San Francisco: Jossey-Bass, 1995, p. 325.

[17] G. Johnson and K. Scholes, Exploring Corporate Strategy, sixth edition ed., Prentice Hall, 2002.

[18] D. H. Walker, L. Bourne and S. Rowlinson, "Chapter 3 - Stakeholders and the supply chain," in *Procurement Systems – A Cross Industry Project Management Perspective*, London, Taylor & Francis, 2007.

[19] H. Mikkonen, Kuntoon perustuva kunnossapito, Helsinki: KP Media Oy., 2009.

[20] K. Komonen, "A cost model of industrial maintenance for profitability analysis and benchmarking," in *International Journal of Production Economics 79*, 2002.

[21] I. H. Hansen, "Performance Measurement of the Maintenance Function within Ecomold Ltd," Agder University College, Grimstad, 2006.

[22] S. Gassner, Deriving Maintenance Strategies for Cooperative Alliances – A Value Chain Approach, 2009, p. 28.

[23] D. H. Shreve, Integrated condition monitoring techniques, IRD Balancing LLC, 2003, p. 63.

[24] J. M. Simões, C. F. Gomes and M. M. Yasin, "A literature review of maintenance performance measurement: A conceptual framework and directions for future research," in *Journal of Quality in Maintenance Engineering*, 2011.

[25] S. Dunn, "Condition Monitoring in the 21st Century," 2009.

[26] L. Parkkila, "Käytön ja kunnossapidon yhdistäminen käynnissäpidoksi," Lapland University of Applied Sciences, Kemi, 2015.

[27] A. O. Al-Mutairi and A. Al-Hammad, "Advantages and Disadvantages of Maintenance Outsourcing in Manufacturing Companies: With Special References to Jubail Industrial City – KSA," in *European Journal of Business and Management. Vol.7, No.20.*, Saudi Arabia, 2015.

[28] T. Wild, "Consignment Stocks - An Opportunity," Control Vol 24 No 10 (December 1998 / January 1999).