ECSEL Joint Undertaking
Electronic Components and Systems for European Leadership

MANTIS

Cyber Physical System based Proactive Collaborative Maintenance

D1.2 Consolidated State-of-the-Art of Sensor-based Proactive Maintenance

Appendix 12:

Existing practices to optimize maintenance decisions in different levels

Work Package	WP1 - Service platform architecture requirement definition. Scenarios and use cases descriptions
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19	VESTAS	Vestas Wind Systems A/S	BEN	DK
20	SIRRIS	Sirris Het Collectief Centrum Van De Technologische Industrie	BEN	BE
21	ILIAS	Ilias Solutions Nv	BEN	BE
22	ATLAS	Atlas Copco Airpower Nv	BEN	BE
23	3E	3e Nv	BEN	BE
24	PCL	Philips Consumer Lifestyle B.V.	BEN	NL
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0.4	2015-10-06	Riku Salokangas	Added contractual date of delivery etc.
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0.6	2016.04.04	Istv□n Moldov□n	
1.0	02/06/2016	Mikel Muxika (MGEP)	Format correction Deliverable info update

Abstract

This appendix contains a description of some of the existing practices in maintenance optimization in various plants and different plant levels and in different type of industries, ranging from process industry to IT. Existing optimization practices require the use of a wide array of different information sources and different tools and a centralized solution for decision support is lacking in most organizations.

Table of Contents

1 Introduction

Maintenance optimisation can be applied to either maintenance plans in general or focused on a single asset or equipment depending on the situation. This document looks into what sort of approaches different organizations and different organizational levels within the organization have to maintenance optimization.

2 Maintenance optimization in process industry in Northern Finland

Current practices utilize maintenance optimisation techniques to a varying degree in different sectors of industry. In for instance paper and steel industry, the maintenance crew are given an annual budget which is then divided between assets according to maintenance plans. Some assets deemed to be important are allocated more maintenance time and a larger piece of the budget.

Utilizing calculations related to failure rates, importance and impact, the maintenance management determines which asset should receive higher attention in the annual maintenance plans. Asset age will also play a role in this plan.

The calculations most managers use adhere to the Finnish maintenance related PSK standards. They are relatively rudimentary calculations, but do provide enough information to keep maintenance effective. [1] Management follows and reports indicators such as the overall equipment effectiveness or OEE, a number that takes into consideration the availability, the performance rate and the quality rate of any system or asset.

For most parts of the maintenance plan the approach is preventive maintenance. Certain parts of a critical process may be placed under constant condition monitoring, mostly when re-fitted with more modern equipment that do have condition monitoring pre-installed. However utilization rate of this data is unknown.

Certain assets are placed under closer scrutiny such as the, now decommissioned, roll slitter at Stora Enso Veitsiluoto paper machine 3. The roll slitter had multiple issues and a lot of monitoring systems were utilized to try to analyse its issues. Most of the systems in use were however meant to monitor performance and the vibrations of the roller and not specifically to monitor its operational condition for maintenance purposes. The roller was under-performing and could never run at designed speeds. It had a tendency to vibrate violently and could launch a roll from the roll set, making it possibly dangerous to run at full speeds. It has since been replaced with a roller from a different manufacturer. The systems installed to the unit would have made condition monitoring possible through comprehensive vibration measurements. This data could have been used for maintenance optimization purposes.

2.1 Maintenance optimization on different levels

Listed here are some of the findings and observation on maintenance optimization done at factories located in Northern part of Finland. These findings date over 10 years of close co-operation with various plants and plant maintenance groups and companies.

2.1.1 Maintenance management

Maintenance management optimization relies on reports from maintenance supervisors and key performance indicators (KPIs) that are calculated from various data sources either manually or automatically.

Through criticality analysis maintenance plans can be optimized per observed asset. Depending on the criticality rating, the asset in question can be let run to failure or placed under various levels of condition monitoring.

Maintenance management is responsible for plant□s desired performance of the maintenance progress and maintenance results. Performance measurement is one way to track maintenance functions. With well-defined performance indicators can potentially support identification of performance gaps between current and desired performance. It also provide indication of progress towards closing the gaps [2]. Maintenance practices should do a cost effective way sparing resources like energy, labour and material costs, because the goal of maintenance manager is to employ a management system that optimizes the use of valuable resources (manpower, equipment, material, and funds) to maintain facilities and equipment. [3]

Performance indicators should not defined in isolation, but should be the result of a careful analysis of the interaction of the maintenance function with other organisational functions. See table 1 a summary of leading performance indicators for maintenance process. [2]

Table 1. A summary of leading performance indicators for maintenance process **[2]**

Category	**Measures / Indicators**	**UNITS**	**Description**	**Recommended Targets**
Work Identification	Percentage of Proactive work	%	Man-hours envisaged for proactive work/Total man hours available	75% - 80%
	Percentage of Reactive work	%	Man-hours used for reactive work/Total man-hours available	10% - 15%
	Percentage of Improvement work	%	Man-hours used for improvement & modification/Total man-hour available	5% - 10%
	Work request response rate	%	Work requests remaining in 'request' status for <5days/Total work requests	80% of requests
Work Planning	Planning Intensity/Rate	%	Planned work / Total work done	95% of all work orders
	Quality of planning	%	Percentage of work orders requiring rework due to planning/All WO	< 3% of all WO
	Planning Responsiveness	%	Percentage of WO in planning status for <5days/ All WO	> 80% of all WO
Work Scheduling	Scheduling Intensity	%	Scheduled man-hours/ Total available man-hours	> 80% of available man-hours
	Quality of scheduling	%	Percentage of WO with delayed execution due to material or man-power	< 2%
	Schedule realization rate	%	WO with scheduled date earlier or equal to late finish date/All WO	> 95% of all WO
	Schedule Compliance	%	Percentage of wok orders completed in scheduled period before late finish date	>90%
	Mean Time To Repair (MTTR)	Hours	Total Downtime/No. of failures	
	Manpower Utilization rate	%	Total Hours spent on tasks / Available Hours	> 80%

Work Execution	Manpower Efficiency	%	Time Allocated to Tasks/Time spent on tasks	
	Work order turnover	%	No. of completed tasks/ No. of received tasks	
	Backlog size	%	No. of overdue tasks/ No. of received tasks	
	Quality of Execution(Rework)	%	Percentage of maintenance work requiring rework	< 3%

2.1.2 Maintenance supervisor

Maintenance supervisor handles work orders and resource allocation and also participates in planning of production shutdown. The supervisor gathers information related to possible faults to help improve maintenance proceedings and make possible alterations to maintenance plans and strategies based on findings. Information sources available to the supervisor are the various CMMS systems in use, factory floor feedback, information available on ERP systems etc.

2.1.3 Work planner

Work planner□s optimizations are related to mean time to repair calculations to allocate resources and spare parts. The plans are inserted into the CMMS and updated as needed. The plans are usually put into use during scheduled downtimes.

2.1.4 Maintenance technician and experts

Maintenance technicians and experts assess work orders received from supervision and work planners. Aside from carrying out the maintenance tasks designated in the orders and reporting the findings into the CMMS, they conduct various condition related analyses on the assets and fault diagnostics. Results of these too are inserted into the CMMS databases.

2.1.5 Operator

Operator□s role in maintenance is increasing. Their tacit knowledge are now starting to be utilized for maintenance optimization. Operators participate in failure analysis and conduct basic condition monitoring activities such as vibration measurement all of which are fed into the CMMS.

3 Maintenance optimization best practices in networking and IT

To meet the expectations about how the IT service should be delivered, IT professionals in increasing numbers have been using the Information Technology Infrastructure Library (ITIL) a set of guidelines and policies that are becoming the standard for IT service.

ITIL is a globally recognized best practice framework that documents the processes, functions, and roles of IT service management. ITIL describes service-management overall in terms of five distinct strands: Service Strategy, Service Design, Service Transition, Service Operation, and Continual Process Improvement.

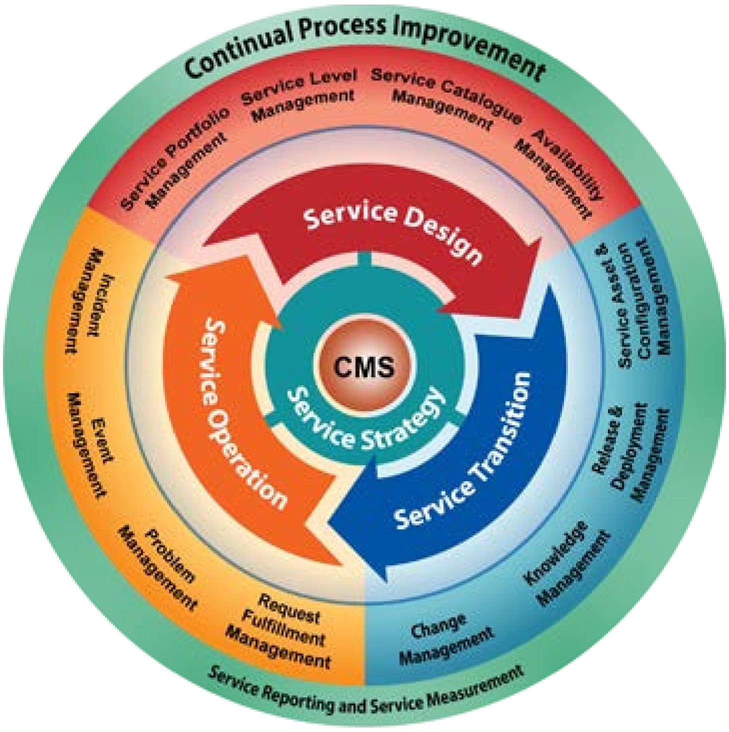

Figure 1 The ITIL service lifecycle

Created in the 1980s by the United Kingdom's Central Computer and Telecommunications Agency (CCTA), ITIL is organized into a series of books, with each book covering different areas of IT management. The current version of ITIL, version 3, is comprised of five books:

1. Service Strategy: focusing each element of the service lifecycle on the customer outcome. Concepts include strategy and value planning, responsibilities and roles, business and information technology strategy linkage, implementation of service strategies, and risks and critical success factors.
2. Service Design: the development of IT policies, documents, and architectures for the design of service solutions and processes. Concepts include service design objectives, selecting the model, risk analysis, implementation, cost, and control & measurement.
3. Service Transition: long term change and release management concepts with guidance on transition into a business environment. Concepts discussed include cultural and organizational change management, knowledge management, and tools & methods.
4. Service Operation: activities required to enable day to day operational excellence. Concepts discussed include change management, processes and function, application management, and scalability.

5. Continual Service Improvement: service quality in the context of continual improvement. Concepts include business and technology drivers, business and organizational improvements, methods and tools; and other best practices.

3.1 ITIL: Service Operation

The purpose of service operation is to deliver agreed levels of service to users and customers, and to manage the applications, technology and infrastructure that support delivery of the services. It is only during this stage of the lifecycle that services actually deliver value to the business. Service strategy defines the value, service design designs the services to deliver that value, service transition brings that design to a live service, and then it is the responsibility of service operation staff to ensure that the service, and thus value, is delivered. Service operation is the phase of the lifecycle that deals almost exclusively with users. For the vast majority of users of the IT service, service operation is IT.

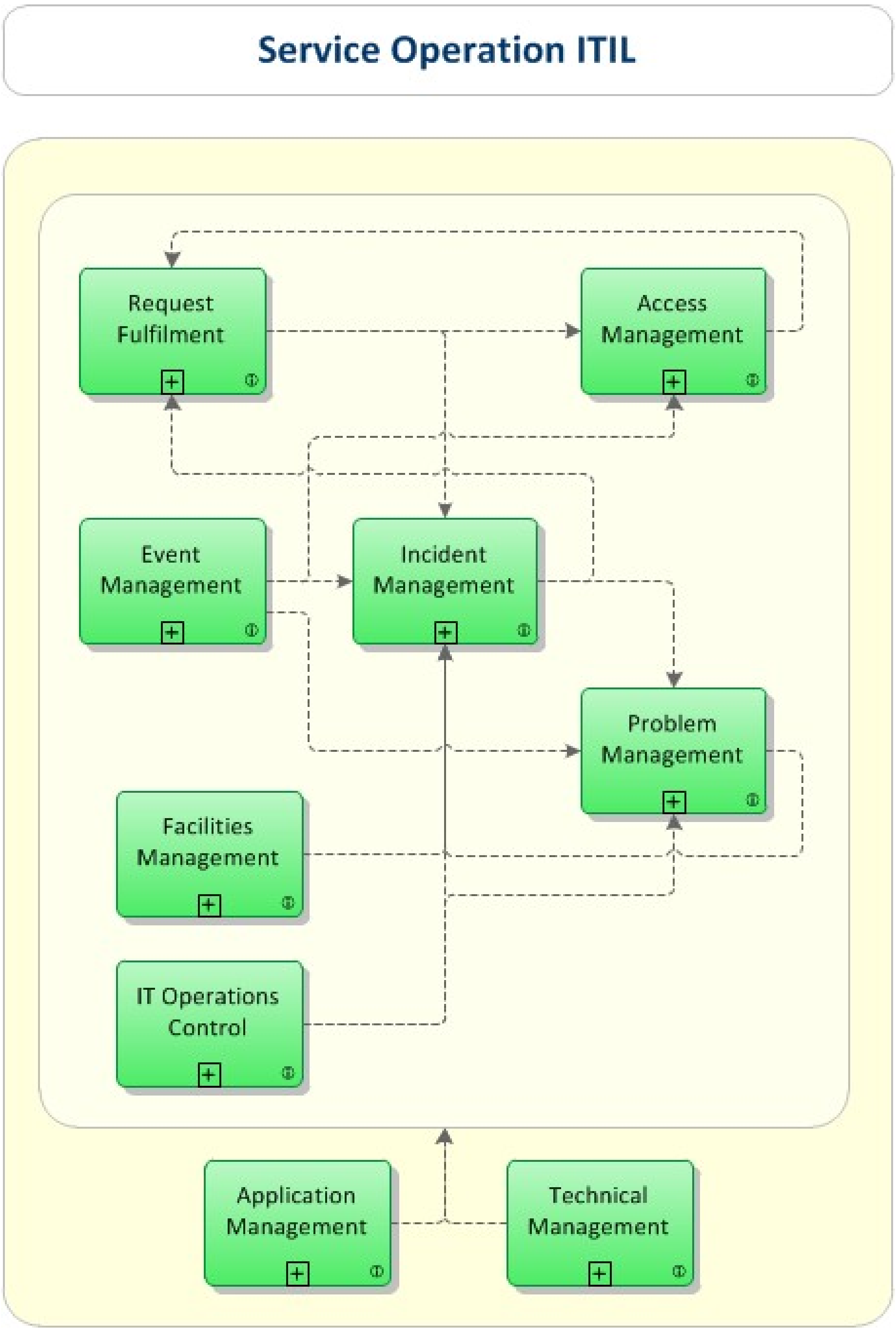

Figure 2 The ITIL service operation

The following main processes are part of the ITIL stage Service Operation:

Event Management - To make sure CIs and services are constantly monitored, and to filter and categorize Events in order to decide on appropriate actions.

Incident Management - To manage the lifecycle of all Incidents. The primary objective of Incident Management is to return the IT service to users as quickly as possible.

Request Fulfilment - To fulfill Service Requests, which in most cases are minor (standard) Changes (e.g. requests to change a password) or requests for information.

Access Management - To grant authorized users the right to use a service, while preventing access to non-authorized users. The Access Management processes essentially execute policies defined in Information Security Management. Access Management is sometimes also referred to as Rights Management or Identity Management.

Problem Management - To manage the lifecycle of all Problems. The primary objectives of Problem Management are to prevent Incidents from happening, and to minimize the impact of incidents that cannot be prevented. Proactive Problem Management analyzes Incident Records, and uses data collected by other IT Service Management processes to identify trends or significant Problems.

IT Operations Control - To monitor and control the IT services and their underlying infrastructure. The process IT Operations Control executes day-to-day routine tasks related to the operation of infrastructure components and applications. This includes job scheduling, backup and restore activities, print and output management, and routine maintenance.

Facilities Management - To manage the physical environment where the IT infrastructure is located. Facilities Management includes all aspects of managing the physical environment, for example power and cooling, building access management, and environmental monitoring.

Application Management - Application Management is responsible for managing applications throughout their lifecycle.

Technical Management - Technical Management provides technical expertise and support for the management of the IT infrastructure.

ITIL Service Operation provides best practice strategies for all management and control processes. ITIL best practice strategies may provide a good starting point to optimize maintenance, starting from the IT infrastructure of the system and can be extended with particular requirements of the given use case.

4 Conclusions

Maintenance optimization is an emerging approach. Insufficient data and labour intensive approaches make it unsuitable for current maintenance management to use as a viable tool. Its usage is still in infancy and requires innovative and reliable software in junction with hardware to make maintenance optimisation approach a viable, everyday tool for maintenance management.

Existing Optimization practices require the use of a wide array of different information sources and different tools and a centralized solution for decision support is lacking in most organizations.

References

[1] P. S. ry, Key performance indicators of maintenance for use in process industry,, PSK Standardisointiyhdistys ry, 2010.

[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] D. Sapp and D. Eckstein, "Computerized Maintenance Management Systems (CMMS)," Plexus Scientific, 17 8 2015. [Online]. Available: https://www.wbdg.org/om/cmms.php. [Accessed 22 8 2015].

[4] ITSMF, IT Service Management Forum (2010) ITIL v3. Information technology infrastructure library. http://www.itsmfi.org

Appendix 1. The relevant standards for Appendix 12

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
IEC	IEC 62264-3	Enterprise-control system integration □ Part 3: Activity models of manufacturing operations management	