ECSEL Joint Undertaking
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 21:

Existing business models related to Proactive Monitoring and Maintenance (PMM)

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Abstract

This appendix 21 analyses existing business models related to Proactive Monitoring and Maintenance (PMM). All business models have the common goal to reduce costs or improve effectiveness. Thereby, a competitive advantage will be gained or maintained.

The business models are divided into three parts. First, there are internal business models, where a company performs maintenance with its own resources in a centralised or decentralised way. Second, maintenance can be partially outsourced. Different levels of outsourcing exist: outsourcing of equipment or system maintenance, outsourcing of low level maintenance during e.g. a scheduled shutdown and outsourcing of maintenance which requires special knowledge. Third, maintenance can be totally outsourced to other companies.

All business models are analysed and also their advantages and disadvantages are shown. Additionally, different approaches to proactive monitoring maintenance are described.

In conclusion, a company has to analyse its own goals and requirements to select the right business model, regarding maintenance. Also maintenance activities performance effectiveness have to be measured and right indicators must be chosen according to the chosen maintenance strategy.

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1 Introduction

The goal of every company is to maintain or gain a competitive advantage. Many approaches and parameters exist, one of them being maintenance. The Mantis project proposal describes the importance of maintenance as:

"*Maintenance is no longer a necessary evil that costs what it costs, but an important function that creates additional value in the business process as well as new business models with a stronger service orientation.*"

Maintenance will increase the lifecycle of a product. In a traditional maintenance environment different kinds of business models between internal and external stakeholders and in maintenance processes can be found (see Appendix 1 and 2). As a result of a shortage in skilled maintenance workers and efforts in minimising costs, maintenance activities have been outsourced. Skilled maintenance workers can offer their expertise to others at lower costs. Thus, there are different types of business models associated with maintenance. They have different goals, advantages and disadvantages. This paper gives an overview of existing business models. First the internal maintenance model is described, existing of centralised and decentralised approaches. Second, different levels of partial outsourcing of maintenance are described. Third, total outsourcing is analysed. All business models are evaluated and their goals, advantages and disadvantages are depicted.

2 Existing business models between stakeholders and in maintenance process

In this section existing organizational business models in maintenance functions are presented: 2.1 internal maintenance model, 2.2 partially outsourced maintenance model and 2.3 totally outsourced maintenance model. A business model can be described as "*the structure of product, service and information flows and the roles of the participating parties*." This also includes potential benefits and sources of revenue to each of the parties. [1] Reim et al. (2015, 65) has collected to his literature review from other authors diverse definitions about business models. Those definitions are presented in table 1. [2]

Table 1. Business model definitions [2]

Author	Business model definition
Meier (2004) [3]	The use of the customer (result dimension) defines the market segments and the corresponding business models on the strategic level.
Richter and Steven (2009) [4]	Business models that are based on the dynamic bundles describe the design of the customer-supplier relationship in the form of performance schemes and responsibilities.
Schuh et al. (2009) [5]	The main aspect in the definition of a business model should be the capitalization and the benefit mechanisms of a company.
Spring and Araujo (2009) [6]	Common themes in business model literature include a concern with network structure; a focus on how transactions are made; revenue models and incentives; and how providers' capabilities are transferred or accessed through products, services, or combinations thereof.
Meier et al. (2010) [7]	A business model can be described by a user model, architecture of value creation and turnover model and by describing the design of the customer supplier relation.
Gao et al. (2011) [8]	A business model depicts the way in which the partners of a business collaborate with one another.

Close relationship and collaboration between stakeholders are essential in maintenance [9]. Maintenance organization itself needs to be very flexible, so it can adjust its necessary capabilities to interact with other internal functions of business, as well as with external partners [10] or shareholders. It is always a company's strategic choice what kind of activities to be externalized and what is the correct level of maintenance outsourcing [11]. These choices have be suited for the company's overall business objectives and strategies.

Internal maintenance is the traditional model of the maintenance business. Some manufacturing companies are shifting their functions more towards service operations. Wandermerwe and Rada (1988, 314 – 315) termed this transfer towards increasing service management "servitization" of business, which is very much a top management issue. The definition states that the "servitization" is: "*Modern corporations are increasingly offering fuller market packages or 'bundles' of customer-focussed combinations of goods, services, support, self-service, and knowledge. But services are beginning to dominate*" (p. 314). [12] Nowadays many companies are moving their maintenance business partly or totally to the outside service providers. Boundaries between product and services are blurred [13].

2.1 Internal maintenance model

The main principle of internal maintenance is to organize the company's maintenance on their own with internal stakeholders. Previously, the use of outside labor wasn't, it was a matter of honor to do the work on your own and keep the machines running and equipment in condition using your own resources. In modern times, manufacturing equipment and machines have become more complicated and their repair requires specialized knowledge and skills. This leads to a situation where it's not viable to rely on the internal maintenance but it is necessary to use external maintenance services. [14] The advantages and disadvantages of internal maintenance are shown in table 2. In this section 2.1 internal maintenance organizational forms are presented, which are centralized and decentralized maintenance.

Table 2. Internal maintenance advantages and disadvantages [14]

Advantages:	Disadvantages:
Maintenance and production work together in the same maintenance department.	Maintenance is not a company's key business area, rather it's a support function for production.
Only one system is needed for both monitoring and communication within the same organization.	Modern devices require complex know-how that is difficult to maintain, particularly competences, that are rarely needed.
Conceptually, production and maintenance personnel expertise is mutually compatible.	Maintenance organization needs a diverse range of skills, so one person cannot control everything. This leads to the fact that the maintenance of the small industry plant will become expensive.
	Old habits and practices in old organizations in the history of the ballast can be detrimental to the development of operations.
	In general, maintenance resources are lower in such organizations that specialize in servicing.

2.1.1 Centralized maintenance model

Process and manufacturing companies traditionally use a centralized maintenance model. In a centralized maintenance model, maintenance acts as its own separate centralized organization. These organizations are traditionally called manufacturing plant/factory service, maintenance unit, service unit, service department etc. In the centralized model, organization has its own centralized functions like machine- and electricity-automation workshops. Centralized maintenance has clear technical advantages and disadvantages, those are presented in table [15].

Table 3. Centralized maintenance model advantages and disadvantages [16]

Advantages:	Disadvantages:
Saving space.	Centralized organization is stiff and shares resources.
Saving storage space.	A large organization is characterized by slowness and inefficiency.
Saving of machine time.	The alienation from individual departments problems.
The uniform and easily moveable labor resources.	Limited data from the production.
Centralized know-how, development and training, as well as action.	Heavy and expensive.
Affordable due to specialization that allows use of specific resources across the company.	From time to time it creates unwanted work for itself and unnecessary storages.
The expert has a meaningful work environment.	Resources are underloaded.
Purposeful management, monitoring and knowledge management.	The substitute problems (specialists).
	Production and maintenance responsibilities and their divisions are unclear.
	Production is not seen as a separate area of responsibility.

2.1.2 Decentralized maintenance model

In the decentralized maintenance model maintenance is placed in the sub-units and under the authority of the production and immediate vicinity of the production equipment. Maintenance personnel are organized in accordance with production, and the persons responsible for maintenance are at the same time process operators or associated closely with process operators and work directly under production authority. The advantages and disadvantages of decentralized maintenance model are presented in table 4. [15]

Table 4. Decentralized maintenance model advantages and disadvantages [16]

Advantages:	Disadvantages:
Flexible and fast service.	Material handling is scattered.
Light and inexpensive.	Warehousing is scattered.
The awareness of production and customers, as well as the product requirements.	Education is scattered.
The ability to make changes and fast decisions.	Risk of resourcing duplication at the enterprise level.
A person will be able to quickly and flexibly handle production tasks, if maintenance tasks are not available.	Flexibility of capacity is difficult to implement.
Resources can be maximised.	Skilled human resources and their vulnerability.
Universally professional personnel.	Expert doing miscellaneous work, which might undermine motivation, unless it has been adequately taken into account enough in targets and training.
Expertise in problem solving at local level.	

2.2 Partially outsourced maintenance model

Maintenance contracting is today one of the fastest growing businesses [17]. Outsourcing can be defined "*...as the delegation of business functions totally or partially to another company along with part of the administrative and operational control.*" [18] By outsourcing maintenance, competitive advantages can be gained. Companies can concentrate their resources and investments on what they do best, their "core" activities. Thus, internal specialists, e.g. an engineer, can focus on his work and does not need to carry out maintenance tasks. Other companies who specialise in maintenance can offer their services. In this way, the return on internal resources can be maximised and the capabilities of maintenance specialists are used. This is especially useful in scenarios, where uptime and precision of equipment is critical to guarantee a workflow. Therefore, the decision of outsourcing is a strategic decision which can reduce costs, optimise resources [11], [19], [20], [21] and achieve competitive advantage through performance improvement [22].

There are several advantages and disadvantages in outsourcing which have to be considered. They have to be judged from a strategic, technical and economic point of view and give an indication whether it is suitable to outsource the maintenance of a specific task. The list is based on [20] and [23], see table 5.

Table 5. Partially outsourced maintenance model advantages and disadvantages [20], [23]

Advantages:	Disadvantages:
Freeing up existing maintenance staff to focus on other important tasks.	Loss of knowledge or skills
Improving staff morale by removing the "dull" task of maintenance.	Loss of control over externalised functions.
Reducing cost at the same quality by employing a specialist.	Dependence on third parties.
Supporting fluctuating maintenance demand with external variable costs.	Loss of security by outsourcing company secrets.
Improving quality by focusing on the companies specialties.	
Improving the company focus.	
Reducing management complexity.	

Different levels of outsourcing maintenance exist. They can be generalised to four steps, as depicted in figure **1** ([21] [22]). First, equipment and system maintenance can be outsourced. Second, low level maintenance can be outsourced, for example during a scheduled downtime. Third, special maintenance tasks can be outsourced which need special knowledge or are of critical importance. These three outsourcing options will discussed in detail below. Last, there is the option to outsource all maintenance tasks. This will be discussed in chapter 2.3 totally outsourced maintenance model.

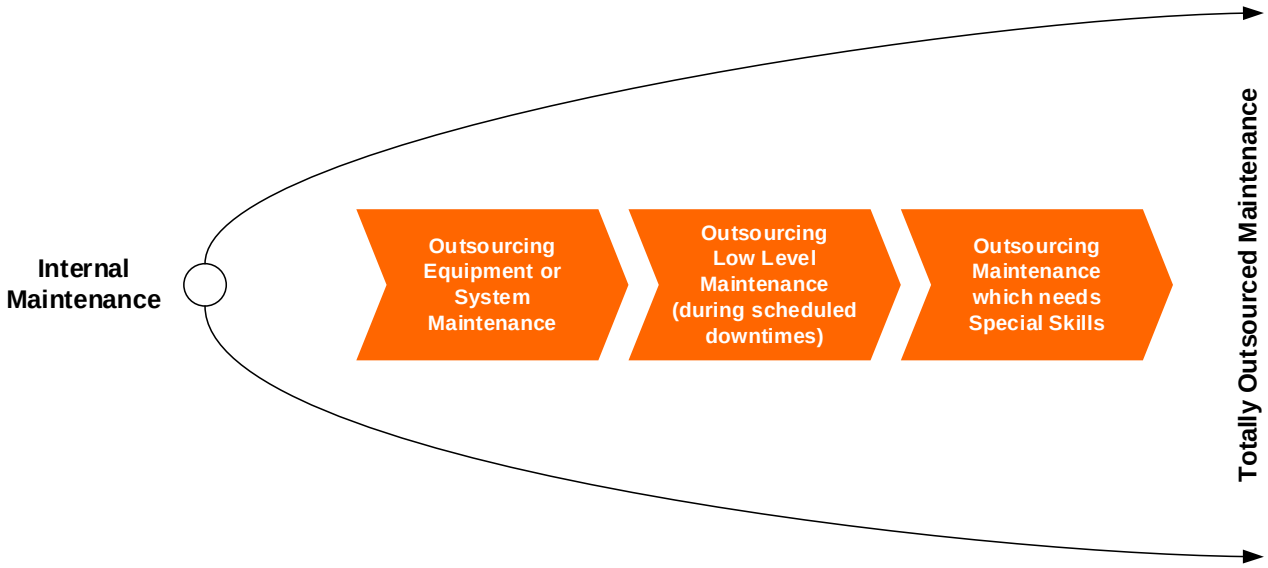

Figure 1. Outsourcing maintenance

2.2.1 Outsourcing Equipment or System Maintenance

Outsourcing equipment or system maintenance is a logical step derived from the customer-supplier model. An equipment manufacturer sells machinery to a customer, usually including aftersales services. Those services may include installation and training. Additionally maintenance service may be offered, in form of e.g. remote monitoring services.

In this way, customer and supplier have common interests, as well as a cooperation to reduce costs. The agreement might be intended to ensure that spare parts and tools are provided to the customer. Therefore, the customer has a guaranteed means of keeping the machinery alive and the supplier has a business model that does not end at the delivery of the machinery. Figure 2 shows an Integrated Maintenance Solution (IMS). [24]

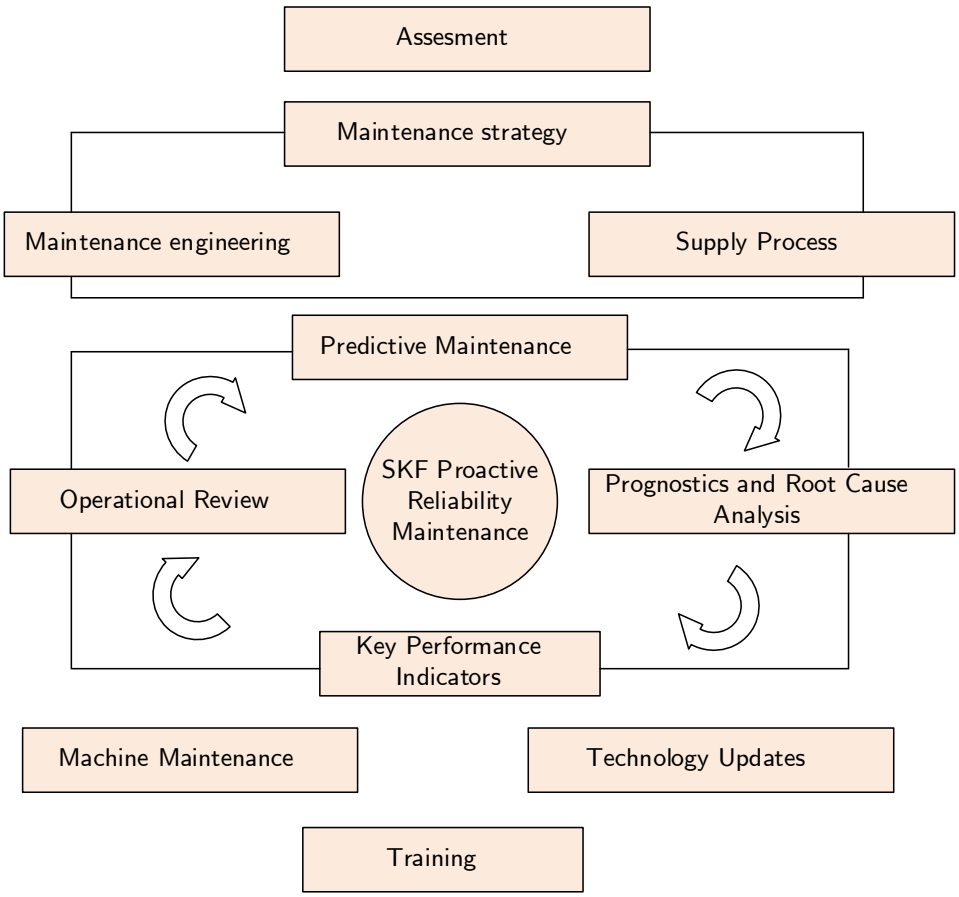

Figure 2. SKF IMS-contract model [24]

This type of maintenance focuses on single entities in a larger environment and has several advantages over internal maintenance. The risk will be shared with the client in order to achieve common interests and basic maintenance is guaranteed for the time of the contract. The customer does not need to "focus" his time on maintaining a stack of e.g. spare parts. [24]

2.2.2 Outsourcing Low Level Maintenance

Outsourcing low level maintenance describes the task of maintenance during e.g. a scheduled downtime. Factory workers perform their shift and focus on their tasks. When the shift ends a contractor can perform maintenance or improvements tasks. 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 [15]. Thus, it is the next level of outsourcing maintenance.

The advantages include, that the factory does not need to employ maintenance workers or their workers do not need to focus on maintenance. Furthermore a scheduled downtime can be used to perform maintenance, so that there is no loss of production time. A contractor who specializes in maintenance will be much more efficient and maintenance can be achieved at a lower cost.

2.2.3 Outsourcing Special Maintenance

The next step in outsourcing is to widen it to tasks which need special knowledge and skills. A maintenance expert is hired to do special measurements, e.g. vibration measurements, rod mill worn parts measurements, data-analysis, wear parts measurements etc. This can be done on a regular basis or the expert offers single visits.

Gaining expert knowledge which is needed for some tasks is cost and time intensive. An expert at this topic can offers his services at lower costs and to many clients. A customer might train their employees to become experts, but special task are often only required in a few cases. This means, that a lot of manpower is wasted.

According to Idhammar (2015) the manufacturing companies which has with fewer than 1,500 bearings in their vibration analyses program can be a good example of where outsourcing of this work can be cost effective [25]. This kind of inspection is usually done when considering whether outsourcing functions or not.

2.3 Totally outsourced maintenance model

Totally outsourced maintenance means that the company of the production process has outsourced the whole of their maintenance department to another company. This outsourced company provides reliability and/or services to the manufacturing organization. [25] The company only has operators who take care of the production process. That's why it's often called operation and maintenance. They usually do corrective maintenance and increasingly operators do condition monitoring rounds and preventive maintenance work.

The Business logic in this models is that the maintenance company's outcome measure is linked to customers production processes annual availability rate. The lower the downtime, the better is a bonus that the maintenance company earns. This is very common in the pulp and paper industry.

Although maintenance actions have been outsourced to another company, there are usually the same maintenance persons who know the manufacturing process, equipment and people. If it is compared between outsourced maintenance and low level maintenance, they didn't necessarily know the manufacturing process, equipment and people so well. That's why the knowledge transfer between outsourced maintenance service provider (supplier) and manufacturing company (customer) is better.

2.4 Monitoring contractors performance

Maintenance activities performance and effectiveness have to be measured somehow. The link can be established between the performances of an item with the maintenance effectiveness when the control activities are performed by the provider. It is extremely important to define a system of performance indicators, mainly they are linked with quality, quantity and costs measures. [23], [11] These measures vary from company to company, depending on current market conditions, the business life cycle, the company's financial standing etc. [26]. Maintenance key performance indicators are presented in standard SFS-EN 15341 [27].

According to Bertolini et al. (2004, 775) the most commonly used measures of contractor's performance are:

- price/cost,
- equipment availability (e.g., MTBF),
- safety and environmental performances (e.g., average number of incidents),
- on-time performance (e.g., MTTR),
- work quality/rework,
- amount of work. [11]

Kumar et al. (2011, 9) did a literature review (figure 3) about key maintenance performance indicators (KPI). These maintenance performance indicators fall into two major categories, maintenance process / effort indicators as leading indicators and maintenance results indicators as lagging indicators. A leading indicator is a performance driver and it alerts the head of the specific organizational unit to verify the present status compared to the referenced one. Those lagging indicators are indicators which indicate the condition after the performance has been taken. It is possible to control the process with these lagging indicators and the leading indicators. Those KPI's must be chosen according to the chosen maintenance strategy. [26]

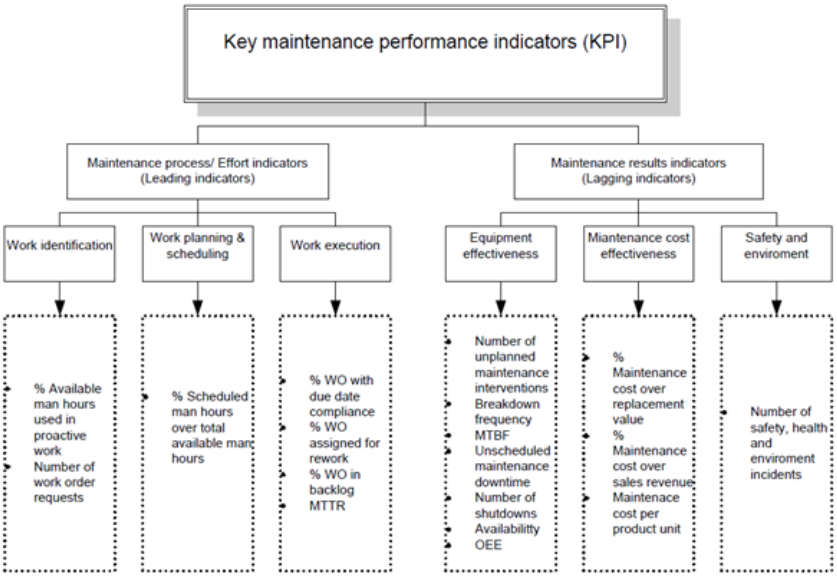

Figure 3. Key maintenance performance indicators [26]

3 From existing business models to proactive maintenance models in the railway context

A large proportion of the costs of the European railway Infrastructure is related to maintenance and the current situation of railway maintenance is characterised as follows:

- The majority of monitoring and measuring systems are designed as independent tools thus making difficult the fusion of information and its integration in the maintenance process.
- A huge number of individual information systems are currently available in the EU railways, each of them dealing with individual and isolated areas of the maintenance process thus not exploiting the potentiality of big data analysis.
- Research and innovation results are showing that maintenance performances are strictly linked to many heterogeneous parameters, most of them not yet taken into account in the maintenance process.
- Typically applied maintenance is still periodic preventive maintenance based on good practices established a long time ago, simply integrated by targeted interventions when faults appear.
- Stakeholders' environment is becoming more and more and complex due to the increasing amount of parties - often with conflicting priorities - involved in infrastructure operation and maintenance.

Taking into this context and also the increasing usage of the railway infrastructure, due to a growing frequency of passenger and freight trains on it, and environmental and safety regulations, the increasing of maintenance requirements cannot be met without a substantial shift in maintenance strategies. This shift and tailor made maintenance approach can only be reached with the necessary tools/systems for information management and decision support. A scalable framework for asset management systems, containing the static and dynamic data from all relevant components of the rail infrastructure can improve lifecycle management, efficient maintenance strategies and adequate operations planning which includes logistic preparation, deployment of staff, tools, equipment and possessions.

The idea is to acquire data with a holistic approach to be able to use different data sources (diagnostics and monitoring systems mounted on rolling stock or along the rail infrastructure) to get new information for the decision making processes. This information can feed the Proactive System Maintenance algorithms with the use of standardised and open interface layer, assuring the extendibility, interoperability and adaptability of the concept and systems developed in future. The data processing done with a holistic approach allow to gather knowledge on asset behaviour (alerts related to the degraded state of railway assets) as well as to derive decisions for planning of maintenance activities, applying innovative principles to the data sets collected from the field or from existing asset registers.

Evaluating complex information from the various sources mentioned above, a reliable predicting model for asset degradation, multiple contingency scenarios and decision support systems will allow to develop maintenance strategies, predictive, risk and condition based maintenance for a substantial cost reduction increasing the reliability, availability and quality of the railway infrastructure. In this context Root Cause Analysis (RCAs) for single failures and related analysis for removal of root causes will guide the decision.

This new maintenance approach will involve/have an impact all the main railway stakeholder: for the infrastructure managers, proactive maintenance results will have an impact on long-term preservation of assets (expressed in RAMS requirements) minimizing life cycle costs, while for the railway operators, proactive maintenance will improve the railway infrastructure availability and reliability. Finally proactive maintenance will provide, to maintenance contractors, more effective and efficient maintenance processes, supporting their decisions/maintenance planning. Here below is reported a table 6 that reassumes the state of art of existing maintenance solutions and the advancements that will be reached throw the new proactive maintenance approach synthetized above.

Table 6. State-of-the art vs. advanced beyond

State-of-the-art	Advance Beyond state of the art
Individual discrete maintenance management systems	Integrated maintenance management system
Reactive maintenance	Predictive maintenance
'Traditional' maintenance fail to take full advantage of enhanced components built-in the network	Advantages of new components are identified and are reflected in lower maintenance efforts
Infrastructure operators having isolated asset status information systems with customised decision support tools	Maintenance decision support tools with standardised interfaces enabling seamless integration of legacy asset status information systems, hence leading to increased interoperability
Maintenance decisions based mostly on static and pure geometric track quantities.	Reliable maintenance decisions based on asset assessment drawing from vehicle-track-environment interaction
'Preventive' maintenance procedures not fully reflecting technology advances and interactions between components involved (e.g. corrugation treatment based only on surface condition)	Predictive maintenance building on total system view of infrastructure and leveraging on condition based maintenance and life cycle cost assessment
Lack of real failure data to carry out reliability analysis (RAMS)	Databases of failure and historical maintenance actions which are the seed for RAMS analysis tools
Immature predictive concepts using asset specific degradation models neglecting uncertainties	Data drive approach. Probabilistic information on condition and risk assessment as base for decision making.
Specific-purpose tools with limited applicability	Generic decision support tool derived from a general-purpose framework, thus easily adaptable.
Use of heuristics based on experience for decision support	Use of mathematical optimisation in proactive planning tools.
Possession take a lot of time to secure before work and much hands on tool time	Advanced work methods. Equipment to automatically secured workspaces within seconds, fast working methods, proactive machinery on in-service trains

4 Conclusions

In this report different maintenance business models have been introduced. There are two main characteristics in the maintenance business models, whether they are arranged with internal workforce / in-house personnel or with external workforce / outsourcing. As a matter of outsourcing, there are two ways to buy maintenance services whether it is arranged partially or totally. Partially outsourced maintenance can be: 1) equipment and system maintenance, 2) low level maintenance (scheduled downtime) and 3) special maintenance tasks. Totally outsourced maintenance means services which are handled by other company. Service company work quite often in tight relationship with manufacturing company. In this appendix 21 are also presented internal maintenance and partially outsourced maintenance advantages and disadvantages. Outsourcing activities have to be judged from a strategic, technical and economic point of view.

Manufacturing companies can acquire partially outsourced maintenance from different product or service suppliers. Usually they can acquire different kind of mixes of maintenance services for example maintenance during production downtime, condition monitoring of equipment or for expert measurements like vibration measurement. Maintenance service business is an increasingly growing business. Usually a company has to choose the correct level of maintenance outsourcing. It depends on their individual needs.

Partially and totally maintenance outsourcing service business and contractor's performance and effectiveness have to be measured somehow. The most commonly used measures of contractor's performance are: price/cost, equipment availability (e.g., MTBF), safety and environmental performances (e.g., average number of incidents), on-time performance (e.g., MTTR), work quality/rework, amount of work. Usually in maintenance there are key performance indicators (KPI) which show maintenance process / effort indicators and maintenance results indicators.

As mentioned inside chapter 3 - "From existing business models to proactive maintenance models in the railway context", the railway sector will refer to more mature ICT sectors like banking, aerospace and finance, whose analytics approaches as already reached system proven in operational environment.

From that sectors It is expected to receive contribution on:

- innovative data mining and analytics approaches;
- innovative approaches for the retrieval, distribution and exploitation of open data.

5 List of appendixes

Appendix 1. Maintenance process with internal stakeholders

Appendix 2. Maintenance process with external stakeholders

Appendix 3. The relevant standards for Appendix 21, WP6 task 6.1 and 6.2

Appendix 1. Maintenance process with internal stakeholders [28]

Stakeholder	Maintenance Management	Maintenance support planning	Maintenance preparation	Maintenance execution	Maintenance assessment	Maintenance improvement
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 *Licences (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	--------	--------	*Assessment 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

Appendix 2 Maintenance process with external stakeholders [28]

Stakeholders	Maintenance Management	Maintenance support planning	Maintenance preparation	Maintenance execution	Maintenance assessment	Maintenance improvement
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	--------

Appendix 3. The relevant standards for Appendix 21, 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
PSK	7901	Maintenance in industry. Service agreement	2001
PSK	7502	Key performance indicators of logistics. Material function	2002
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
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
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	55000	Asset management -- Overview, principles and terminology	2014
ISO	55000	Asset Management Standard: What Maintenance Reliability Professionals Should Expect	2015
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*

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