LEAN SMART MAINTENANCE

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Abstract

Maintenance is a strategic factor and key enabler for smart factories. Therefore, it needs to be intelligent – SMART – and cost-efficient – LEAN. The Lean Smart Maintenance (LSM) concept combines these two perspectives and enables a dynamic, smart and value-oriented maintenance/asset management for smart factories. This paper introduces LSM and explains its major components. It consists of efficiency drivers, e.g. maintenance processes and planning, outsourcing, and effectiveness factors, e.g. data and knowledge management, qualification and maintenance strategy. Besides that, an LSM implementation model is introduced. An LSM assessment methodology as a first implementation step is explained. A maturity model is used to identify and improve the current state of asset management. The four-step LSM implementation model is described with a maintenance strategy example.

1. Introduction

Industry 4.0 is an evolutionary change for the technological future. At the same time, it is a challenge. Furthermore, maintenance has to become involved in this process. To develop itself towards the requirements of Industry 4.0 as well as to be a key component in the value-added process. This process takes place in companies, which have to perform in global competitions in a dynamic environment in which factors such as volatility, complexity, and ambiguity sometimes appear simultaneously. A change towards Industry 4.0 is a change from the conventional factory to the "Smart Factory".

What does this mean for maintenance?

At the moment TPM and Lean Management are two of the most widely used concepts in maintenance. (Bernerstaetter et al., 2018) To keep up with the technological change, it's important to support the development of maintenance concepts towards Industry 4.0 by suitable concepts like LSM. LSM – combining lean philosophy and smart maintenance – provides a model of a dynamic, smart and value-oriented maintenance management system containing different aspects. These aspects describe the interrelations in maintenance in all relevant aspects and management levels. Additional LSM includes a process model, the possibility to optimize the maintenance strategy dynamically based on value-oriented criteria and an implementation model, which is presented in the following paper.
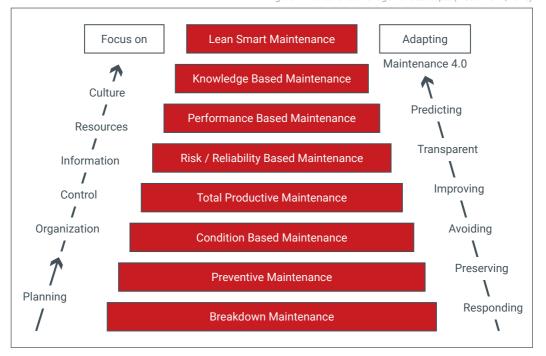
Figure 1: Maintenance management concepts (Biedermann, 2016)

2. Concept

The LSM approach is a sophisticated maintenance concept, which is characterized thru a lean and learning orientation as well as a risk and resource-oriented alignment. The objective is to improve efficiency and effectiveness of asset management. This leads to a value-creating partnership between production and maintenance department. Figure 1 shows the development of maintenance management concepts. From break down maintenance over an increasing value creation contribution and maturity towards Lean Smart Maintenance.

The smart part represents the effectiveness perspective of LSM. Smart Maintenance stands for an intelligent and learning maintenance management focusing on continuous improvement. Classic input control – cost-oriented – is replaced by an output control, oriented on value creation contribution and reliability, availability, maintainability, and safety (RAMS). The lean part represents the efficiency perspective of LSM. The philosophy is loss reduction on the input side of maintenance management system. Resource conservation underlines the sustainable orientation. (Biedermann, 2016)

Figure 2: Categories of LSM management system

Corporate philosophy	Mission statement for Maintenance	Target system	Maintenance strategy	Structural organization
Process organization	Spare parts management	Maintenance controlling	Continous improvement	Data and information management
Use of technology	Qualification	Motivation	Knowledge management	Leadership and change management
	Maintenance prevention	Outsourcing	Autonomous maintenance	

The management aspects of LSM presented in Figure 2 are divided into four different categories: framework conditions (red), structural capital (light grey), human capital (white) and relationship capital (dark grey). Following their requirements concerning LSM's high maturity level are introduced.

Corporate Philosophy and Mission Statement for Maintenance

The corporate philosophy forms the basis for the mission statement for maintenance. The mission statement is important for all members of the maintenance organization. It is building the foundation for their actions. Consequently, every employee has to be able to identify themselves with the mission statement. To ensure this, the mission statement should be developed "bottom-up" and not "top-down". (Kinz, 2017)

Target System

The target system regulates maintenance goals according to content, dimensions and time period. In LSM the target system: (Biedermann, 2008; Schroeder, 2010)

- is focused on value creation contribution.
- is derived from enterprise targets.
- is oriented on economic, ecologic and human factors.
- is integrated into the maintenance control loop and dynamically adapted.
- comprises a written maintenance missions statement.

Maintenance Strategy

Maintenance strategy refers to general procedures and rules which determine object-related maintenance measures according to content, methodology, and scope in a specific chronological sequence. Following criteria characterize this management category in LSM: (Biedermann, 2008; Kinz & Biedermann, 2015)

- All possible strategies – break down, preventive, condition based, predictive and pro-active – are mixed asset specifically under economic and risk-oriented perspectives.
- Maintenance strategy mix is adapted dynamically to changing conditions.
- Assessment tools concerning of risk and cost criteria are used to classify all assets.
- Strategy selection process is integrated into the maintenance control loop.

Structural Organization

The structural organization of maintenance department specifies hierarchies, competencies, responsibilities, and degree of decentralization. In LSM the structural organization fulfill certain criteria, like: (Biedermann, 2008; Schroeder, 2010)

- Interdisciplinary teams (semi-autonomous working groups) are responsible for operation and maintenance in a defined shop floor area.
- Structural organization is dynamically adapted to changing conditions.
- Autonomous maintenance is established and accepted by employees.
- The Span of control allows appropriate leadership and motivation.

Process Organization

Maintenance process organization comprise of planning and controlling of all maintenance activities. This includes, among others, the following criteria, according to LSM: (Schroeder, 2010)

- Comprehensive maintenance master data is available in an actual state.
- Capacities are planned deterministic.
- Initiation, implementation, monitoring, and feedback of each maintenance activity is done by the use of a standardized system and improved continuously.
- The efficiency of maintenance tasks is measured on the basis of standard times.
- Non-productive and non-value adding times are recorded and reduced.

For example, by analyzing maintenance processes, non-value adding activities are identified. These activities do not contribute to a higher reliability or availability. Such activities should be reduced to a minimum.

Spare Parts Management

The spare parts management in LSM is characterized thru: (Biedermann, 2008)

- The spare parts management system is highly integrated with connections to all necessary functional areas (E.g. CMMS, purchasing, controlling, quality).
- A cost-optimal service level is pursued for the majority of spare parts.

For example, an assessment helps to identify critical spare parts. It builds the foundation of an efficient and lean spare parts management strategy. Models for breakdown predictions contribute to reduced storage costs.

Maintenance Controlling

Maintenance controlling has the task of coordinating and controlling maintenance measures as well as to provide information for problem-solving and decision-making processes. Key performance indicators (KPIs) are used to identify deviations between the target and actual state. In LSM maintenance controlling fulfill criteria like: (Biedermann, 2008)

- All necessary asset dependent sources of loss are recorded (OEE).
- Cause-effect relationships between enabler aspects as well as efficiency and effectiveness factors are transparent.
- The controlling loop is completely closed.
- Strategic success dimensions are integrated into the controlling system.
- Controlling system is continuously improved.
- The budgeting process is future and risk-oriented.
- Allocated maintenance costs are classified at least into planned and unplanned in-house, external and material costs.

Continous Improvement

In an intelligent system like LSM continuous improvement is obviously necessary for all relevant management categories. Special Focus should be on: (Schroeder, 2010)

- A suggestion scheme for continuous improvement is installed. Majority of employees participate and premiums are transparent and accepted.
- Change is initiated top down as well as bottom up. Resistances are identified and managed.
- Interdisciplinary teams are responsible for weak-point analysis and problem solving according to defined standards.

Data and Information Management

Appropriate management of information and data is a very important success factor and

a key enabler for smart factories. Related to LSM several factors are crucial: (Biedermann, 2016; Kinz & Bernerstaetter 2016)

- Horizontal and vertical integration of computerized maintenance management system (CMMS).
- Economical application of technological resources (E.g. condition monitoring systems, mobile devices, visualization tools, ...).
- The necessary interface between technological resources, ERP-System and CMMS are solved properly.
- Data is seen as a resource. For each data source a producer, owner and user are defined.

Use of Technology
A dynamic, smart and value-oriented maintenance is characterized by the focused and economically meaningful use of technology. The enhancement of learning and the creation of value is paramount. Prior to a company-wide roll-out, innovative technologies are tested during pilot projects and gain from continuous improvement. (Kinz, 2017).

Qualification, Motivation and Knowledge Management
Concerning human resources shortage of skilled professionals and demographic change are challenges for maintenance. Especially in highly mature systems like LSM several topics need to be focused: (acatech, 2015; Biedermann, 2016)

- A knowledge management system is used to externalize and safe knowledge of experienced employees and to provide it to new ones.
- The balanced ratio between methodical, soft skill and technical qualification activities according to current requirements.
- Intrinsic motivation is used to support employee's potentials.

Leadership and Change Management
Leadership culture and a management system are important for maintenance management. Chosen concepts and styles influence the efficiency and effectiveness, but depends on the situation and corporate structure.

Maintenance Prevention
Maintenance prevention stands for the early management of new equipment. Up to 60 percent of an assets lifecycle costs are fixed in early stages of planning and construction. Knowhow of maintenance department needs to be considered in these early phases of investment to reduce costs during operation. LSM criteria in this category are: (Al-Radhi & Heuer, 1995; Schroeder, 2010)

- Defined standardized specifications for new assets and equipment.
- Standardized acquisition process for new assets involves maintenance department.
- Continuous improvement of standards and processes.

Outsourcing

External procurement of maintenance services is called outsourcing. The reasons for outsourcing are linked to expected benefits, which are basically based on the strategic success factors: cost, quality, time and flexibility. Outsourcing processes in LSM fulfill certain criteria, like: (Schroeder, 2010)

- Outsourcing is oriented to own core competencies.
- Core competencies are determined according to maintenance strategy.
- Service relationships are long-term oriented and regulated with service level agreements.
- Transaction costs are recorded and optimized.
- Supplier assessments are used to optimize service relationships.

Autonomous Maintenance

Maintenance activities carried out by machine operators in coordination with the maintenance department are called autonomous maintenance. The maintenance management has to ensure, the activities are consistent with the main maintenance targets and strategies of the company. In addition, the activities have to support the other named aspects. (Kinz, 2017)

3. Process Model

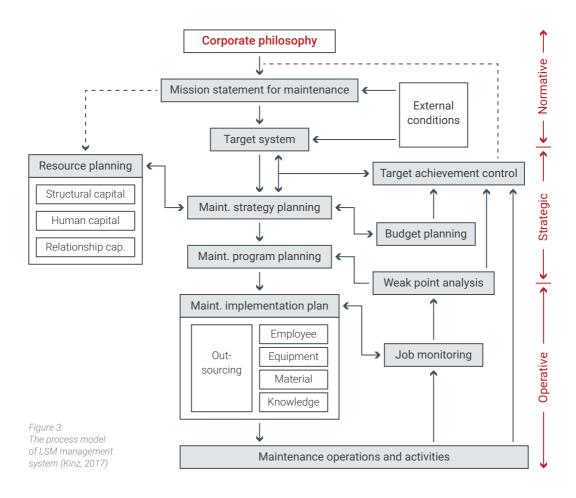Figure 3 presents the process model of LSM. The model contains a controlling system and four control loops:

- the operational control loop,
- the operational-strategic control loop,
- the strategic control loop, and
- the normative control loop.

The controlling system supports dynamic improvement as well as the learning environment inside the organization and increases efficiency and effectiveness. Next to the coordinating and controlling role inside the organization, the controlling system is responsible for the coordination of external aspects/environment and the internal aspects of planning, organization, controlling and personnel management. (Kinz, 2017)

4. Dynamic Maintenance Strategy Adaption

The selection of a suitable maintenance strategy mix for each asset is a major factor towards an increasing value added. It strongly affects the effectiveness of a maintenance system. But most organizations determine their maintenance strategy mix static. A dynamic adaptation to changing conditions is a key element of LSM. Figure 3 shows the maintenance control loop in which strategy planning is a central process step. Information on operative mainte-

Figure 3:
The process model
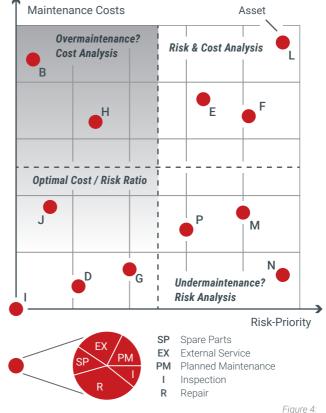*of LSM management*
system (Kinz, 2017)

nance should be reflected in the monitoring, weak point analysis and target controlling step. Findings of this reflection step help to recognize changing conditions for the proper maintenance strategy and deliver input for the next strategy planning period.

With a customized risk assessment tool critical assets of a production system and their risk potential could be identified. This is an important step in the process of finding a suitable maintenance strategy and helps to concentrate limited resources on critical assets. Depending on the companies requirements a few possible assessment tools are available. For a comprehensive risk orientation, a classic risk assessment method is recommended. To consider different risk and cost oriented perspectives a criteria assessment tool should be used. As a result, the risk potential of each asset is quantified in a risk priority number (RPN). (Kinz & Biedermann, 2015)

RPN and maintenance costs constitute the two dimensions of an asset prioritization portfolio (Figure 4). The highest occurring RPN limits the x-axis and the highest maintenance

costs limit the y-axis. Assets in the lower left quadrant are unobtrusive concerning risk and cost. Assets in the upper left quadrant should be analysed regarding over maintenance – focus costs. Assets in the lower right quadrant should be investigated concerning under maintenance – focus risks. Assets in the upper right quadrant need to be analysed regarding costs and risks. Maintenance strategy conclusions could be derived from the asset prioritization portfolio and the risk and cost analyses. (Kinz & Bernerstaetter, 2016)

For a dynamic strategy adaptation, a periodic review of the asset prioritization portfolio needs to be done. The inclusion in the maintenance controlling loop is recommended. (Biedermann, 2008)

Figure 4:
Asset prioritization portfolio (Biedermann, 2016)
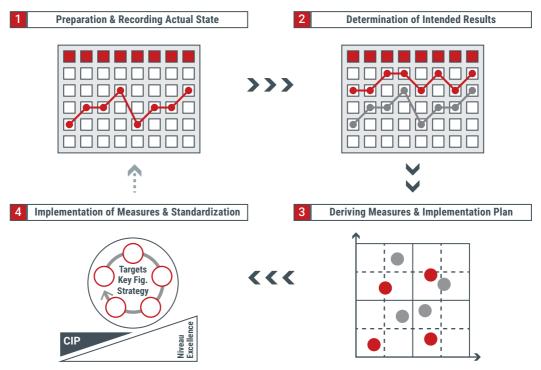
5. Implementation Model

This chapter introduces a four step process model for LSM implementation, which is shown in Figure 5. The model helps companies manage the change from a reactive maintenance management towards a dynamic, smart and value-oriented asset management. Change management is a central success factor and needs to be focused in each implementation phase. Following, the four phases of LSM implementation model are described in detail. The management aspect of maintenance strategy is used as an example.

Preparation and Recording Actual State

As a first step, an LSM assessment is used to identify the actual state of maintenance management in all LSM management aspects, introduced before. Maturity level models proved to be suitable instruments for this kind of change process. Therefor the categories are integrated into a five stage maturity level model. Information for assessment is collected with maintenance questionnaire, semantic analysis, benchmarking and interviews in all hierarchical levels and relevant departments. (Kinz, 2017)

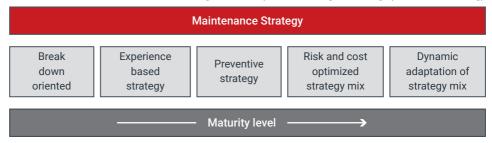*Figure 5: The implementation model of Lean Smart Maintenance*

As an example Figure 6 shows the five maturity levels of the aspect of maintenance strategy. The keywords representing every level should be defined and supplemented separately. Level one stands for a break down oriented maintenance strategy without any planned activities. At level five a risk and cost optimized strategy mix is dynamically adapted to changing conditions. This would fulfil the requirements of LSM.

Determination of Intended Results

Based on the actual state the project team determines the intended results. Industry benchmarking, as well as corporate strategy, should be taking into consideration. Usually, it is

Figure 6: Maturity levels of management category maintenance strategy

possible to improve by one to two levels of maturity model, but it is possible to have short- and long-term targets. (Kinz, 2017)

Deriving Measures and Implementation Plan

In the third step measures to reach the intended results are specified. By analyzing definitions of the target maturity level and comparing those with the actual state, potentials in each category can be identified. In interdisciplinary workshops, these potentials are discussed. The result of phase 3 is an measure plan for all maintenance management aspects and an implementation plan. Regarding the plan, it is important to be aware of the resources it takes and the effort next to the daily business.

In the maintenance strategy example, the current stage could be maturity level three – preventive maintenance. Target is level five - dynamic adaptation of cost and risk optimized asset specific strategy mix. Potentials are a dynamic strategy adaptation and a cost as well as a risk assessment of assets. Measures are:

- Development and application of an asset risk assessment tool.
- Identification of asset specific maintenance costs classified as planned and unplanned in-house, external and material costs.
- Implementation of asset prioritization portfolio into dynamic maintenance control loop.

Implementation of Measures and Standardization

In phase 4 the measures are implemented and standardized. Project management, progress check with suitable KPIs and periodic controlling meetings are important instruments in this phase. Experience has shown that it makes sense to implement certain measures in pilot areas first and roll them out after successful pilot implementation.

Sustainable standardization of the achieved new status is the final part of step 4 of LSM implementation model. A lot of change projects fail because results and new processes are not integrated and standardized into daily business. The behavior of management is very important in this phase – supported by, e.g.: (Kinz, 2017)

- process descriptions of new procedures,
- internal training,
- communication and visualization, and
- awareness building measures in middle and lower management.

6. Conclusion

LSM combines the economic principles of an efficient input and output oriented asset management with a learning and knowledge based approach. It supports maintenance management to outline the contribution to a sustainable company's success. An efficient and effective asset management as the main objective can be achieved. LSM supports maintenance management in its evolution towards smart maintenance and enables transformation towards a smart factory.

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