MAINTENANCE MANAGEMENT SYSTEM

HANA PACAIOVA, JURAJ GLATZ

Technical university of Kosice, Safety and Quality Production Department, Kosice, Slovakia

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e-mail: hana.pacaiova@tuke.sk

Maintenance Management requires acceptance of basic systems approach, i.e. implementation of company goals to management goals. Well know Maintenance management philosophies (TPM, RCM, RBI) applied in order to improve processes, often remain only on the basis of the implementation of services without the need for full integration into existing management systems.
Misunderstanding the nature of maintenance management leads to inefficient step, resulting in a contradiction between the goals of management and their ability to support real goals through maintenance management.
Process approach in the management of maintenance is the basis for improvement in maintenance and hence achieving the required performance.
This article, based on practical experience, analyzes the root errors caused by maintenance management in order to apply the selected philosophy in the management of maintenance without the knowledge or lack of willingness to accept a systemic approach to maintenance management.

KEYWORDS
risk management, TPM, RCM, FMEA, KPI

1 INTRODUCTION

In industrial practice the basic effort is to reduce costs and increase profits. Often it happens by the changes, respectively manufacturing processes innovation. But we always talk about technological processes, which effort is to reduce their energy consumption, while taking into consideration the entire life cycle of technology systems, as well as selection of suitable maintenance strategy in order to minimize losses and waste.
Maintenance as combination of all technical, administrative and management activities during the object´s life cycle in order to maintain or restore it to a state where it can perform required function, has an impact on safety, environment, product quality, total profit, respectively loss of company. As follows from the definition of [EN 13 306, 2001], maintenance is not only the task of ordinary employees working on the maintenance position, but it is mainly management role into which it is necessary to include each employee of the company. Different management philosophies help to monitor targets companies, often with the support of specific management systems (quality, environment, safety, information safety). It often happens that these systems do not correspond with the goals of maintenance management and have little or even controversial impact on its management.

2 BASE PRINCIPLE OF SYSTEMATIC APPROACH IN MAINTENANCE

Management system is a set of interconnect processes that brings to the organization increased efficiency and effectiveness in achieving determined objectives.
Process is defined as a set of activities using resources and regulations to enable the transformation of inputs into outputs. The process approach represents identification, interaction and process control in such way that the output of one process is presented as input to the next process. This relation can be understood as the certain interconnection of process [Nenadal et al. 2008, Popovic 2010].
Continual improvement of the organization's performance needs to be taken as a major goal of any kind of organization!

2.1 Maintenance Management & Systematic Approach

Maintenance terminology [EN 13306, 2001] understands maintenance as a process which includes management, administrative and technical activities in order to maintain or restore equipment into the required state. In the introduction requirements on safe and quality maintenance are pointed out. Into account are also taken requirements on control of environmental impacts and costs effectiveness.
In some literatures [Pacaiova et al. 2011, Dhillon 2008] states, that maintenance costs are in range from 20% to 35% of production costs. More than 25% of accidents in underground mines happen during maintenance. More than 10% of loss of production time happens due to corrective maintenance, etc.
Each of these indicators appeals to "backlog" (reserves), which results not only from the so-called: direct maintenance costs but mainly from so-called: induced costs, which result from deficiency of maintenance planning.
It is important that maintenance management is aware of not only the principles of system`s management, but also the tools and sources for strategy decision and maintenance activities based on analytical approaches and methods, such as:

- Root Cause Analysis (RCA)
- Failure Modes and Effects Analysis (FMEA/FMECA – Criticality Analysis)
- Fault Tree Analysis (FTA)
- Hazard and Operability Analysis (HAZOP)
- Human Error / Reliability Analysis (HEA/HRA).

Certain methods are indicated as standard analytical methods and are usually accompanied by the criticality analysis, i.e. analysis of critical equipment which criteria correspondent to those areas where management of the company points out steps by its policy or through company goals (sources and responsibility). In these areas will be used precautions to prevent unwanted - uncontrolled loss (safety, environment, quality, information safety, cost, etc.).
Maintenance strategies (see Fig. 1) are therefore focused on prevention of the failure mode, where failure of equipment has its "critical" impact on desirable results (goals) or at a "tolerable" risk is a maintenance strategy focused on repair in case of failure occurs [Pacaiova et. al 2009].

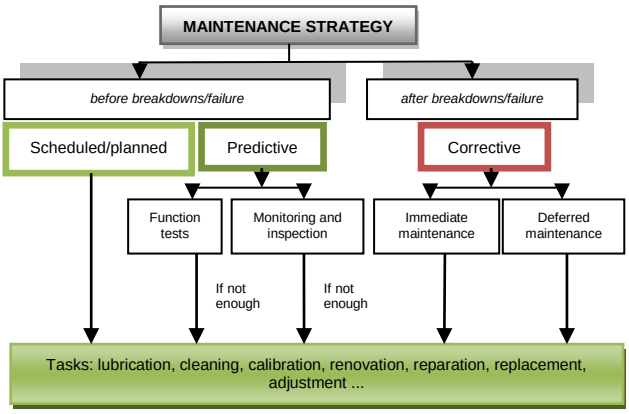

Figure 1. Maintenance strategy and maintenance tasks

We know two basic maintenance strategies:

- preventive - focused on prevent of failures
- corrective - focused on efficient repair of equipment after the failure occurrence.

Preventive strategy in a simplified context may be scheduled "fixed" by time, mileage, cycles, etc., or may be performed when "monitoring state" of equipment would lead to an accident (we call it predictive maintenance strategy).

Criteria of choosing the maintenance strategy in the planning phase are specified areas of seriousness losses, as a result of failure – i.e. loss of equipment function, and may be threat of set goals of the company. It is mainly in areas of:

- safety of company employees,
- public safety close to company surroundings,
- threat of environmental requirements,
- loss of production quality or delivery delay ,
- loss of company property or foreign ownership,
- the high costs spent on equipment repair in case of failure,
- losses affecting the region's economy or economy of all society.

Nowadays in companies we can also often find criteria such as "loss of company image" as a result of major industrial accidents.

Assurance of the company goals is possible only if there are provided sources and support from company management, so that these goals could be transformed into maintenance management goals, see Fig. 2.

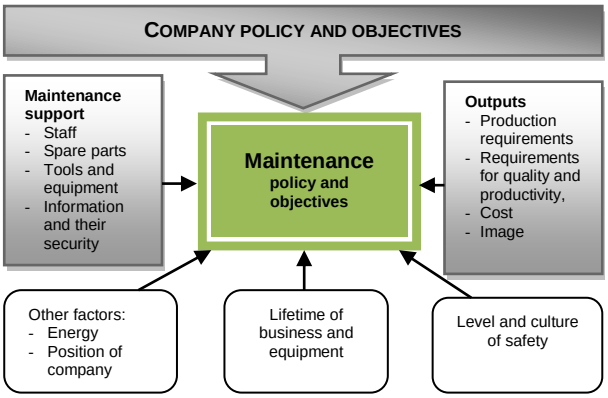

Figure 2. Factors influencing of maintenance goals

2.2 Maintenance Philosophies

Planning in maintenance management requires the application of such analytical methods which are able to ensure adequate support (maintenance support) for the implementation of planned activities based on the specified management goals (Maintenance Task Analysis, Criticality Analysis).

Nowadays in the maintenance management are well known mainly the following philosophies, which are completely or with minor editing suitable for most industrial companies, as described in Tab. 1:

- TPM – Total Productive Maintenance developed in Japan as a conception of maintenance management including all departments, i.e. from management to manufactory, controlling support of company's maximum productivity based on increase principle of production equipments effectiveness. Author of the TPM conception is Seichi Nakajima, who gradually studied systems for preventive maintenance in 50tees a 60tees years (Preventive Maintenance) in the USA a Europe [Rakyta 2010].
- RCM – Reliability Centered Maintenance presents systematic approach for identification of effective and preventive equipments and their elements maintenance activities according to specific procedures and proceedings based on intervals defined to perform single maintenance activities. It was developed when maintaining planes of Boeing 747 a 777 type in the USA and in 1960 - 1970 it was officially elaborated as a base for maintenance management mainly in aircraft industry (technical standard SAE JA1011).
- RBI – Risk Based Inspection is an assessment and risk management process, which evaluates loss risk of pressure equipment's content influenced by materials deterioration. This risk is controlled by equipment's inspection. That means that the priorities of maintenance activities are defined according to analyses and risk assessment.
- RIMAP - Risk Based Inspection and Maintenance Procedures is a result of European project (5 framing project EU 1998-2002), which goal was to develop unitized optimal approach to inspection and maintenance activities based on risks assessment in industrial companies).

	RCM	TPM	RBI
USED IN PHASE OF LIFE CYCLE	Design, Operation and maintenance	Operation and Maintenance	Design, Operation and maintenance
MAIN USED IN INDUSTRY	Chemical, petrochemical, gas, nuclear	Automotive, brewing, food, manufacturing	Chemical, petrochemical, gas, nuclear
CRITICALITY FILTER	ABC*	ABC	ABC
OBJECTIVE	Max. reliability and safety	Max. effectiveness and availability	Health, safety and environment
METHODS	**FMEA, Ishikawa**	**OEE*, P-M***	**FTA, ETA, social risk assessment**

**ABC - equipment categories – A, B, C, OEE – Overall Equipment Effectiveness, P-M – Analysis*

Table 1. Examples of Maintenance philosophy application

3 FROM MAINTENANCE MANAGEMENT TO ASSET MANAGEMENT

In the area of machinery safety and other technical systems, according to the Directive 2006/42/EC, there is clearly formulated requirement of integration of safety aspects into design phase of machinery (not excluding the whole life cycle), with respect to given goals of a company. This principle is base philosophy in company´s physical assets management strategy,

which requires implementation of process tools at all management levels.

Integrated care for assets, Asset Management (AM) is focused on optimum management of assets life cycle so that all strategic objectives of an owner are fulfilled – either physical body or company [Hladik, 2013, Grencik 2013, Snah and Littlefield, 2009].

According to the EFNMS (European Federation of National Maintenance Societies), AM is based on systematic and coordinated decision making, actions and procedure by which the organisation:

- identifies potential strategic physical assets,
- successfully manages especially their performance, risks and costs during the whole life cycle,

and this with the objective to achieve the strategic goals of the organisation.

3.1 Relation between Asset management and Maintenance

In the publication [Legat et al. 2013], physical asset management, as it was understood in the past, has been defined as a program of its acquisition, utilisation and maintenance, based on set of rules, methods, procedures and tools for optimising of effects of costs, performance and risks during its life cycle, see Fig. 3.

Although the term of risk is mentioned in this definition, its relation to corporate objectives is not clearly specified. Usually the term of risk has been associated with the occupational health and safety (OH&S) area.

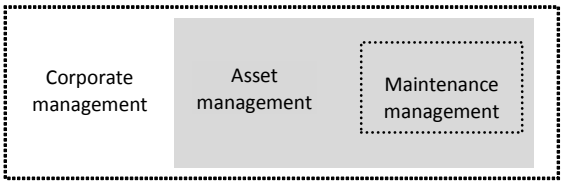

Figure 3. Hierarchy of management processes

On the other hand the definition of corporate management [Legat et al. 2013] specifies "the process of leading, administrating and directing a company. Business tasks often performed by corporate management might include strategic planning, as well as managing company resources and applying them toward attaining the company's objectives".

In the past, reliability was understood as one of quality parameters of a product / item.

In several publications and presentations [Legat at al. 2013, Fangucci and Caltanissetta 2010, Nenadal 2010] it is pointed at the fact that very often has been neglected, while is decisive, implementation of dependability management (reliability, maintainability, maintenance supportability and other requirements) as part of sub-implementation phases. Dependability management in broader understanding is important – specific part of quality management system which is inseparable component of corporate management.

3.2 Asset management and Risk management

Standard 31000 has changed the definition of risk from "the chance of something happening that will have an impact on objectives" to "the effect of uncertainty on objectives".

While managers will continue to consider only the risk evaluation and risk managers to consider the possibility of risks occurring, they should now apply risk treatment options to ensure that the uncertainty of their agency meeting its objectives will be avoided, minimized or removed.

In a company it is important to identify possible areas of losses, which might have influence on given corporate objectives. It is possible to specify them, e.g. in a production company, as follows:

- equipment effectiveness
- personnel effectiveness
- resources consumption effectiveness
- safety level
- production quality level
- environmental protection level
- legislative requirements conformity
- corporate image.

Another approach to risk management is the standard from the year 2002, which has been a result of work of the Committee of Sponsoring Organizations of the Treadway Commission (COMO, USA), objective of which was to prevent scandals on markets concluding from insufficiently assessed risks. This committee created integrated approach to risk management to support businesses and other entities assess and enhance their internal control systems.

It defines: "Enterprise risk management (ERM) is a process, effected by entity´s board of directors, management and other personnel, applied in strategy setting and across the enterprise, designed to identify potential event that may affect the entity and manage risk to be within its risk appetite, to provide reasonable assurances regarding the achievement of entity objectives.

AM is based on these principles of integrated management, as it is given in ISO 31000 or in ERM. First of all it requires the identification of strategic physical assets, that is those, which are important for given corporate objectives, on the other hand assessment their risks, that is an analysis and management of factors and conditions affecting these strategic physical assets in achieving required objective during the whole life cycle of the assets.

3.3 Tool for Risk assessment in AM frame

In general, the principle of risk management comprises respecting the following fundamental steps:

a) Risk analysis and Risk assessment
- Determination of the object boundaries
- Identification of threats and hazards, determination of likelihood and consequences.
- Risk estimation as a combination of Probability (P) and Consequences (*C*)

b) Risk evaluation
- Risk assessment (acceptability, tolerability)

c) Risk control.

Establishment of measures, i.e. determination of barriers according to legislative requirements and internal regulations (e.g. ALARP system = As Low As Reasonably Practicable), [Lauwers 2010].

The selection of suitable methodology for risk assessment and control is based on:

- Effectiveness and simplicity of algorithm
- Extent covering the scope and required functions of assessed system/operations
- Comprehensibility
- Transparent accessibility of conclusions
- Feedback possibility.

In case of AM the process of risk management can be describe as follow:

a) Risk analysis and Risk assessment;
- Determination of the object boundaries – plant, technology, equipment

– Identification of threats and hazards, determination of likelihood and effects state on objectives
– Risk estimation as a combination of Probability (*P*) and *Objective Effects* (*E*)

b) Risk evaluation
– Risk assessment (acceptability, tolerability)

c) Risk control – through *integrated effective and efficiency measures*.

The Risk management process can be presented as a list of coordinated activities, represented by 7Rs and 4Ts:

– **R**ecognition or identification of risks
– **R**anking or evaluation of risks
– **R**esponding to significant risks
  – **T**olerabe (To)
  – **T**reat (Tr)
  – **T**ransfer (Tf)
  – **T**erminate (Te)
– **R**esourcing control
– **R**eaction planning
– **R**eporting and monitoring risk performance
– **R**eviewing the risk management framework.

The following table describes proposal of possible methods for implementation of ISO 31000 principles into AM.

Lifecycle phase	Requirements	RM tools
Concept, Intention	Formulation of requirements on equipment – in relation to determined objectives, functionality, reliability, durability, legislation conformity	What if? Effects criticality
Project	Specification of equipment parameters, conditions of reliability and maintainability, commenting	Risk diagram FMEA* HAZOP LOPA
Realization (production)	Monitoring of equipment assembly (rotation machines, reserved equipment, maintenance support (capacity, qualification, facilities)	FMEA HAZOP
Implementa-tion (test operation)	Equipment commissioning, testing, documentation, technical data verification (technical manuals)	FTA ETA FMEA HAZOP LOPA
Operation and maintenance	Taking to permanent operation, proactive maintenance, condition monitoring (data collection and analysis)	FTA ETA FMEA HAZOP LOPA
Disposal	Safety disassembly, minimum environmental burden, effectiveness	FMEA HAZOP

* *FMEA – Failure mode and effect analysis, FTA – Fault tree analysis, ETA – Event tree analysis, HAZOP – Hazard and operability study, LOPA – Layer protection analysis*

Table 2. Implementation RM tools into Asset Management processes

4 CONCLUSIONS

Principle of integration of management systems by means of implementation of risk management currently seems to be very actual and effective, in particular in industrial companies where is a need to introduce measures in respect to the importance of activities and hazardous factors. Decision process of corporate management cannot be only specific and unilateral because the complex of hazards is nowadays becoming, as from external as well from internal environment, a recognised factor available for public. Requirements on safety for protection of life and health of personnel have been transferred on the external environment in which a company is performing and there is even pressure increasing on co-responsibility of corporate managers overlapping frames of a country or state in which the company is performing (Directive 2008/114/EC).

This important aspect brought by ISO 31000 needs creation of suitable methodology that could by certain unified manner help the asset management to assess in the most objective way their activities in relation to given objectives, so that the decision making and control of measures was economically effective and morally acceptable for all interested parties.

Planning maintenance strategies and performance of maintenance activities can bring required effect only if it is based on system tools and tools assigned for risks assessment of run and maintained technical equipment. Dynamic maintenance program must takes into account any operation changes and equipment conditions that are part of risk analysis and its goal must be process of continual improvement.

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CONTACTS

prof. Ing. Hana Pacaiova, PhD.
Technical university of Kosice, Faculty of Mechanical engineering, Safety and Quality Production Department
Letna 9, Kosice, 04011, Slovakia
+421903710474, e-mail, hana.pacaiova@tuke.sk