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To cite this article: A Nagyova and H Pacaiova 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **393** 012005

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Maintenance evaluation based on the EFQM model excellence

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Abstract. Maintenance and its processes became during last decade a very important part of an organization management. It significantly helps to avoid failures, eliminate accidents, reduce machine repairs and minimize costs and corrective actions. Manufacturing organizations use different types of tool and methods to manage maintenance processes but also for their assessment. Especially now, when new standard ISO 9001:2015 with Risk-Based Thinking approach arrived, organizations are convinced to integrate “old types” of methods with “new trends” of understanding. The implementation of maintenance system is the best way how to ensure the effective maintenance activities, which are controlled but they miss systematic approach with exact requirements. The idea of systematic approach should also be added in maintenance system in the same way, as is it in Asset management. According to this ideology the Maintenance Model (PMM) was designed, which is based on the EFQM structure. The aim of the paper is present the mentioned model, which does not follow requirements of the standard ISO 9001 but helps to assess, if organization is able to meet commitments, given by management and also its ability to follow different criteria.

1. Introduction

In order to ensure requirements of any management system, it is essential to recognize what the real needs are and what the organization wants to achieve. One of the quotes attributed by the guru of Quality, Dr. Deming is “if you can’t measure it, you can’t manage it.” Even there are more critics about the statement, the organizations always try to find a way how to improve their processes through data, reports, analysis or the results of audit. The maintenance, as we know it today is also the area which tries to improve and adopt new techniques and methods for its performance evaluation. The most known way how to evaluate processes in Maintenance Management System is Audit. According to [25] there are several types of methods of audit performance, such as audit surveys, report analyses, different management models or indicators. Based on the professionals skills, requirements of other organisation, The Slovak Maintenance Society (SSU) has set in 2014 a goal to create a product for knowledge and skills testing in maintenance processes management, based on modern management requirements, by using the P-D-C-A (Plan-Do-Check-Act), as well as the EFQM model criteria. The model has been developed (based on prof. Pacaiova research) to implemented structure named as the Maintenance Performance Audit (MPA). MPA assess the maintenance management policy and its compliance with organization policy, maintenance objectives setting, maintenance execution processes and their evaluation. This monitors the set performance evaluation indicators with the use of standardized indicators (e.g. EN 15341) for improving the maintenance processes.



2. Maintenance management audit models

Generally for performing management audit, each management system should follow rules and requirements given in ISO 19011 Guidelines for quality and environmental management systems audits. This guide provides a structured approach and framework to control any management audit [26]. To be more specific, it is necessary to realize that Maintenance management audit is defined as a comparison between the existing maintenance processes and the specified maintenance requirements. An unachieved difference between the existing maintenance management and the standard requirements is called a 'gap'. A good maintenance report shows all organization gaps and provides the right answers to bridge them. Even common 'maintenance standards' such as ISO 16646 Maintenance - Maintenance within physical asset management to support ISO 55001 Asset Management requirements are used along with other similar standards. It is wrong to presume that an asset management standard or maintenance standards actually contain any true best practices. Maintenance audits can also be done against in-house maintenance requirements. Many maintenance consultants and professionals have their own maintenance audit criteria and maintenance audit checklists which they use to audit client sites [27]. Different authors have proposed models, frames or systems seeking to manage maintenance in the best way [15]. For example, Duffuaa and Raouf (1996) conducted a study on continuous maintenance productivity improvement using a structured audit; they propose a structured audit approach to improve maintenance systems [18]. They suggest, that for the best maintenance evaluation is to monitor factors, such as: organization and staffing; labor productivity; management training; planner training, craft training, motivation, management and budget control, work order planning and scheduling, facilities, stores, material and tool control, preventive maintenance and equipment history, engineering and condition monitoring, work measurement, incentives and information system. They also propose root cause analysis to develop and improvement action program [18]. On other side, in [3] a multi-criteria model for auditing for a Predictive Maintenance was introduced, developed and later also implemented. The model has a two-level structure, with top level auditing areas specified by second level auditing criteria on which the performance of the Predictive Maintenance Program should be appraised. This structure resulted from the analysis and discussion of an internal questionnaire to the management, technical and consulting staff of auditing organization. This also guided the association of a performance scale with each criterion, describing several reference levels of accomplishment. Well known is a performance measurement system based on a number of key performance indicators (KPIs) and the Balanced Scorecard (BSC) created by Kaplan & Norton (1996) [8]. Very similar concept has the model, presented in [1] which uses qualitative and also quantitative evaluation. The model is trying to use survey and also indicators for monitoring.

A qualitative method proposed by Tavares (2001) is focused on maintenance radars assessed through surveys [1]. Quantitative evaluation is also used in Balanced Score card methodology, which allows the alignment of performance indicators to the proposed strategy for Planned Maintenance pillar (vision, mission and objectives) in four perspectives: financial, clients, internal process and learning & growth. Also, it provides a strategic map showing the dependency relationship (cause-effect) between the performance indicators to support actions (strategic initiatives) that the maintenance function must carry out in a continuous improvement cycle. BSC methodology is closely linked with the major Total Productive Maintenance (TPM) concept, which has been developed from the original preventive or productive maintenance. TPM uses 8 different pillars to reduce losses. Another similar concept, which can be used as a model for maintenance audit is World Class Maintenance (WCM) [27]. Concept is considered as an integrated approach to perform asset maintenance comprehensible for all participants in an industrial organization. WCM creates opportunities to make the work processes more efficient and effective in a way that these are universally applicable to increase the safety, economy and overall efficiency of the assets. A well-defined WCM work process can offer a unique business opportunity with minimum costing to the assets' owner whilst increasing significant return on investments [27]. Maintenance Capability Plot (MCP) as a template for and objective maintenance audit. MCP was completed by using a targeted questionnaire covering the key factors for world class maintenance.

Questions were grouped into the key areas of maintenance management as Organisation Culture and Employee Empowerment Performance Measurement Maintenance Tactical Delivery: Work and Contractor Management Processes Maintenance Process Improvement Asset Management Strategy Budgeting and Cost Control Reliability Improvement Planning and Scheduling Materials Management Information Technology [26].

3. Common structure for maintenance management system

The implementation of any type of standards is voluntary, although in some sectors it has become an obligatory measure, given the coercive influence of customers [14], [15]. Also, research has been done on how far these types of standards have a significant impact on business performance, with some studies finding a positive link [4], [10]. However, there is a consensus with a large number of studies which have analyzed the benefits that may be obtained from MS implementation and certification [5], [11], [12]. Management system in today's terms is understood not only as a management methodology, but also as a necessary step to successfully achieving the vision and goals of the organization. Optimally adjusted system allows not only transparently manage processes but helps to reduce the amount of disagreements, minimize costs and ensure efficient production and service provision. It is a common practice that the organization does not control its activities only on one, but often on two or on more systems. ISO organization provides a list of the international management systems, which are implemented worldwide. In 2012, ISO issued a document marked as Annex SL (Proposals for Management System Standards). Annex SL - Proposals for management systems standards according to which all international newly adopted or revised standards shall have a uniform HLS (High Level Structure) framework based on the Plan - Do - Check methodology. The reason for issuing the Annex SL was to seek formal unification of all management systems standards by providing a uniform structure. According to Annex SL, all international standards of management systems shall have a uniform structure in form of ten chapters:

1. Scope
2. Normative References
3. Terms and Definitions
4. Context of the Organization
5. Leadership
6. Planning
7. Support
8. Operation
9. Performance Evaluation
10. Continual Improvement

The benefit of HLS structure will be to facilitate the integration of management systems in the organization. As already mentioned, the Annex SL is based on the PDCA cycle. Chapters 4 - 7 are included in the Plan phase, Chapter 8 in the Do phase, Chapter 9 in the Check phase, and the Chapter 10 in the Act phase (Figure 1), [21]. Through the structure is very important to accept the new philosophy in Management Systems, which is Risk Based Thinking (R-bT). R-bT must be applied in all processes of the organization, regardless what the subject of the business is!

Many of the management systems (e.g. Quality management system, Environmental management System, Information Security Management System...) have already adopted the new structure. Some of them, e.g. Health and Safety Management System are still on „waiting list“. Unfortunately, there is no announcement to publish the international standard in Maintenance Management system yet. Generally, organizations already use supporting standards such as ISO 55001 Asset Management requirements; ISO 16646 Maintenance - Maintenance within physical asset management, BS EN 15341 Maintenance. Maintenance key performance indicators to keep and evaluate their maintenance processes, but those cannot replace the added value of the regular management system. If the maintenance management system with the 10 Chapters structures exists, it would help not only implement maintenance requirements to the organization processes, but also to perform maintenance audit.

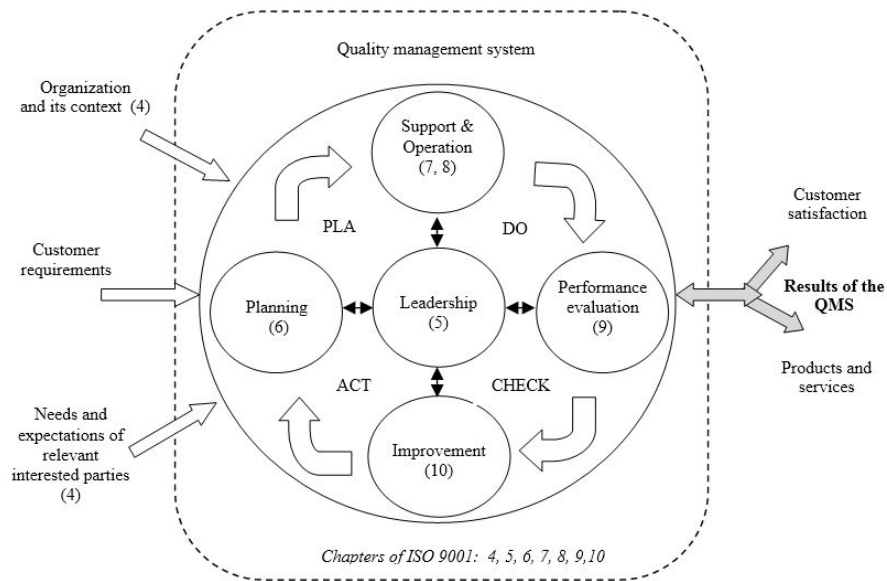


Figure 1. Model of QMS on the basis of PDCA cycle with HLS structure incorporated, [21].

4. Maintenance audit based performance maintenance model

As mentioned before, there are many possibilities to perform the maintenance audit. According to the few demands from organization, gained skills and available sources, the Slovak Society for Maintenance (SSU) in cooperation with maintenance managers in Slovakia and Technical University of Kosice proposed Performance Maintenance Model (PMM) as a tool for the Audit Maintenance. The idea and the structure were adopted from EFQM model, which is closely linked with process self-assessment, [28]. PMM inserted into EFQM model has 11 single criteria (instead 9), divided into 2 areas (Figure 2):

- Enablers criteria (with maximum 500 pt) forming areas, such as Leadership, Policy and Strategy, People, Budget, Processes – Spare Parts and Services, Planning and Scheduling.
- Results criteria (with maximum 500 pt) consist of Customers and Employees Results – Corrective Activities, Key Activities Results – Evaluation of Effectiveness, Measuring and Improvement, CMMS, Availability, Society Results – Safety and Environment.

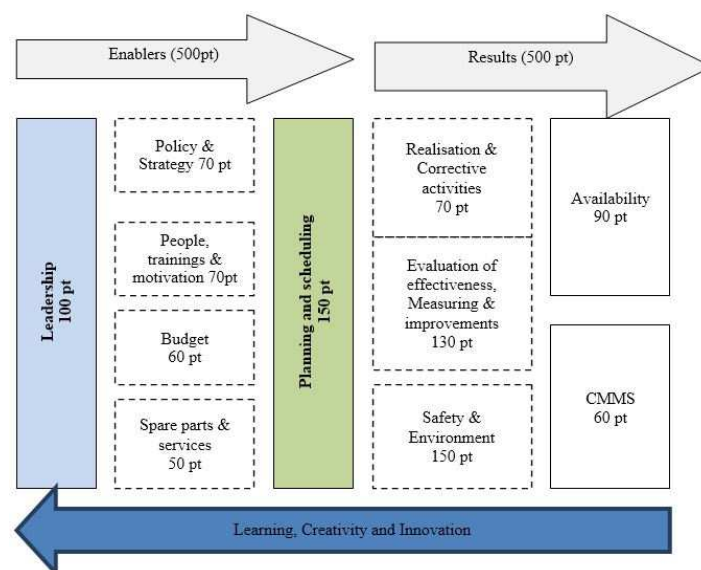


Figure 2. Performance Maintenance Model - PMM

4.1. Enablers of Performance Maintenance model

Enablers in the model can be described following:

Leadership - represents the conceptual role of maintenance management, which consists of two principles:

- development goals clearly formulated by maintenance management (mission, vision, policy, conduct code, etc.);
- activation, initiation, motivation of all maintenance staff by maintenance management in line with the specified goals.

The Policy and Strategy - assesses the way maintenance management introduces its mission and vision through a clearly focused stakeholder strategy (organization policy and objectives) supported by relevant maintenance management policy, plans, objectives, tasks and processes.

Policy and strategy must fully reflect company culture, structure and activity, taking into account the orientation, priorities and needs of different stakeholders. Policy and strategy must reflect the approach to implementation of the modernization process and the change management process.

Human resources (employees) - need to be activated by participation in creation of values and company culture. Communication is an important tool. This criterion describes the way the organization manages, develops and makes knowledge available, as well as the way it applies the potential of its staff at the individual, team, and organization level, and how it plans these activities to support its own policy, strategy, and the effective operation of its own processes.

The Budget and Spare Parts and Services assesses the way a company plans and manages its partnerships and internal resources to support its own policy and strategy and the effective operation of its own processes. The intent of this criterion is to assess to what extent a company can effectively and efficiently manage its resources.

The Planning and Scheduling - represents the maintenance processes management. A prerequisite of good maintenance are activities to be systematically managed from the beginning to the end of their course in the organization. Maintenance processes must have their owners, they are understandable, and their upgrading and improvement is based on daily active participation of all employees for the sake of full satisfaction and value for their customers and other interested parties. Measurement and feedback are essential for effective work of maintenance management.

In order to achieve a unified rating ranging from 0 to 10 points, each question has the own coefficient to assure maximum achievement in the model (Table 1).

The total score for each criterion is given as:

$$Ts = \text{Number of questions} \times \text{Maximum rating} \times \text{Coefficient} \quad (1)$$

Table 1. The enablers' criteria of the PMM model.

Enablers Criteria				
Criteria	Number of questions	Maximum rating	Coefficient	Total Score
Leadership	10	100	1	100
Policy and strategy	14	140	0,5	70
Human resources	20	200	0,35	70
Budget (costs planning)	20	200	0,3	60
Spare parts and services	20	200	0,25	50
Planning and scheduling	50	500	0,3	150
Ts - Total score	132	1340	-	500

4.2. Results of Performance Maintenance model

Results in the model can be described following:

Realization & Corrective Actions - evaluates achievement of results in relation to customers and employees. Performed post-disruption operations and maintenance must be based on risk analysis and cost effectiveness assessment. Corrective maintenance activities must be subject to regular reassessment through measurement and customer satisfaction analysis.

Maintenance Effectiveness Assessment - serves to review the key maintenance activities. It represents all maintenance achievements related to the planned performance. The key performance indicators are specified in the maintenance standard EN 15341, which does not exclude the creation of company's own key indicators. Measurements may refer to parameters such as, malfunction/readiness, productivity, accessibility and processing of information, response time to demand (e.g. repair requirement), maintenance cost effectiveness, etc.

The Safety and Environment - examines the results achieved in relation to the society requirements. The criterion is aimed at measuring the results that the enterprise generally achieves in meeting needs and expectations of the local, national and international community. This includes company's attitude to the quality of life, the environment, the protection of global resources, and the use of its own internal indicators of business efficiency.

CMMS - covers safety support and information system used in the company.

Availability – describes how the organization prepared to major accidents prevention is. The same methodology is used for the Results Criteria (Table 2). The total score for each criterion is given the same as:

$$Ts = \text{Number of questions} \times \text{Maximum rating} \times \text{Coefficient} \quad (2)$$

Table 2. The results criteria of the PMM model.

Results Criteria				
Criteria	Number of questions	Maximum rating	Coefficient	Total Score
Realisation & Corrective Activities	10	100	0,7	70
Evaluation of effectiveness, Measuring & improvements	26	260	0,5	130
Availability	20	200	0,45	90
CMMS	10	100	0,6	60
Safety & Environment	60	600	0,25	150
Ts - Total score	126	1260	-	500

5. Methods for overall rating

For allocating the condition of each criterion, results and enablers were divided into several sections according to the score, which they achieved (Table 3). To get the most objective results, the each range was described by the particular score achievement (Table 4).

Table 3. The results criteria of the PMM model.

PMM Criteria						
Results Enablers	0 - 100	101 - 180	181 - 280	281 - 360	361 - 440	441 - 500
0 - 100	I	I	II	II	III	III
101 - 180	I	II	II	III	III	III
181 - 280	II	II	III	III	IV	IV
281 - 360	II	III	III	IV	IV	V
361 - 440	III	III	IV	IV	V	VI
441 - 500	III	IV	IV	V	VI	VI

Table 4. The Assessment of the PMM level.

	Criterion	Description	Maximum score in Enablers	Maximum score in Results
I.	Critical Without a management concept – corrective strategy prevails.	Insufficient leadership & planning level, possible lack of policy and setting maintenance objectives. No methodology support of the maintenance planning.	0 - 180	0-180
II.	Insufficient Planning carried out based on original manufacturer documentation – the age of the devices not taken into account	Despite significant results, there are major deficiencies in management and maintenance planning. Missing own methodology for maintenance planning. Maintenance does not have its own management concept; it applies the concept of other management systems (e.g. ISO 9001).	181 - 360	0-360
III.	Initial Planning is based on the methodology, concept is partially embedded, and objectives are set. Missing measurement.	Planning is based on the methodology, the concept of maintenance management is partially established, and objectives are set. The company has an established management system and applies some maintenance management tools.	361 - 500	0-500
IV.	Average Objectives are clearly specified, the concept, improvement and measurement established.	Maintenance management is systemic, the concept is established, policy is followed and the goals are set. Measurement of KPI in maintenance has some shortcomings; the improvement process is not systematically controlled.	181 - 500	101-500
V.	Significant The maintenance management concept is implemented, objectives are set, planning is dynamic, performance in line with the plan, planned maintenance prevails, (corrective less than 30%), regular measurement (KPI) is introduced. Efficiency of equipment above 85%.	Maintenance management is on good level, the concept is set, and maintenance policy is based on the policy and objectives of the organization. Preventive maintenance prevails resulting from history and failure cause & consequence analysis. KPIs are set and measured. Shortcomings are a rather formal nature, some improvements needed here.	281 - 500	281-500
VI.	Excellent Maintenance management concept is implemented, goals are set, planning is dynamic, performance in line with the plan, planned maintenance prevails, (corrective less than 10%), regular KPI measurement is introduced. Efficiency of equipment above 88%.	Maintenance management can be defined as excellent. Maintenance management has long been a major partner in production and management of the organization. Mutual communication based on a friendly base prevails. Seeking common solutions with other departments of the organization is highly professional and team-based. Responsibility is clearly defined with a high level of motivation. Improvement is a constituent of all departments (including maintenance), it is understood as support for competitiveness and long-term development.	361 - 500	361-500

6. PMM results

The proposed PMM model was implemented in 5 different companies where the performance measurement audit was provided. The total score, which companies achieved, was dependable on many reasons. The main factor which influenced the score was the level of maintenance controlling, especially if the company has or has not implemented TPM (Table 5).

Table 5. PMM verification.

Organization	Enablers (max. 500)							Results (max. 500)					TOTAL SCORE	AREA OF PRODUCTION
	Leadership	Policy & Strategy	Human resources	Budget	Spare parts & services	Planning and scheduling	Realisation & Corrective activities	Evaluation of maintenance effectiveness	Safety & Environment	Availability	CMMS			
Producer 1 (Head lights production)	60	18	60	60	21	62	36	62	79	21	38	517	Automotive	
Producer 2 (Rear lights production)	65	40	55	56	30	70	40	56	100	30	32	574	Automotive	
Producer 3 (Gear box production)	80	62	68	60	48	126	64	100	148	88	40	884	Automotive	
Producer 4 (Cheese production)	52	9	36	21	28	45	15	2	68	5	22	303	Food and Drinks	
Producer 5 (Beer production)	55	5	35	60	9	48	5	40	40	5	0	302	Food and Drinks	

According to the results, the rate of score was designed (Table 6), where:

$$R = \frac{T_s}{1000} \times 100 [\%] \quad (3)$$

Table 6. Score chart.

ORGANIZATION	Ts - TOTAL SCORE	R - RATE
Producer 3 (Gear box production)	884	88.4%
Producer 2 (Rear lights production)	574	57.4 %
Producer 1 (Head lights production)	517	51.7 %
Producer 4 (Cheese production)	303	30.3 %
Producer 5 (Beer production)	302	30.2%

According to results, it is obvious that the higher score was achieved in Producer 3 – 88.4% (Gear box production). This company implemented TPM 10 years ago and they provide maintenance audit every year on regular base. The next higher score was achieved in the Producer 2 – 57.4% (Rear lights production) a Producer 1 – 51.7% (Head lights production). Both of these companies are from automotive area, so it is obvious that they have and also use TPM as one of the tool for improvement. Producers 4 – 30.3% and Producer 5 – 30.2% do not have TPM and that's the factor which influenced results as well as their level of maintenance.

7. Conclusion

The Excellence EFQM model is a practical, voluntary framework (tool) that allows organizations to assess where they are on their way to excellence. It is the instrument helping to understand their key strengths and potential shortcomings in relation to the specified vision and mission. Therefore, it is understandable that this tool is used to evaluate processes at all levels of management and individual areas. The Performance Maintenance Audit designed by the Slovak Maintenance Society in cooperation with Technical University of Kosice (author: Pacaiova, H.) verifies the management processes and maintenance organization in relation to the requirements of production, safety, production quality, environmental protection, and cost efficiency. It aims to verify the usefulness of effective planning, management, implementation and evaluation of maintenance tasks to ensure efficiency and improvement of production process. For maintenance level evaluation was proposed and also verified performance maintenance audit. The model is very similar to EFQM model and according to the results, it is clear that for higher score achievement it is very helpful if the organization has implemented tools or methods for maintenance improvement.

Acknowledgments

This paper was developed within the project VEGA 1/0904/16: The utilization of processes capability and performance and products dimensional tolerances in the management of material consumption and related economic, energy and environmental consequences (MINIMAX-3E).

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