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ISO 9000:2015 QUALITY MANAGEMENT PRINCIPLES AS THE FRAMEWORK FOR A MAINTENANCE MANAGEMENT SYSTEM

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Many companies are seeking to gain competitive advantage with respect to cost, quality, service and on-time deliveries. The effect of maintenance on these variables has prompted increased attention to the realm of maintenance as an integral part of productivity improvement. The Maintenance Management Framework is a strategy, a form of guidance and a tool indispensable to the maintenance department to attain quality, efficiency, and effectiveness in performing its mission responsibilities. In a company benefiting from a quality management system, this framework should be founded on the seven principles of quality management according to ISO 9000:2015.

Keywords: maintenance management, quality management principles, ISO 9000:2015

1. INTRODUCTION

Although quality management systems are widely adopted by many firms in their effort to increase organizational capabilities, the payoffs from this program have often been limited because of unreliable or inflexible equipment. Therefore, it is important to include maintenance management in the quality management concept. Typically, managers perceive maintenance as a low status activity, and treat maintenance as a cost generator. They do not realize the great potential of a well performed maintenance. A lot of studies and research conducted by academicians and practitioners has shown that maintenance has a direct impact on productivity and quality (Arsovski, Pavlović, Arsovski, Mirović, 2009, p. 709-714; Fakher,

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Nourelfath, Gendreau, 2014; Khan, Darrab, 2010, p. 341-353; Kutucuoglu, Hamali, Iran, Sharp, 2001, p. 173-195; Madanhire, Mbohwa, 2015, p. 796-801; Narayan, 2012, p. 183-195; Takata at al, 2004, p. 643-656).

Now many companies have shifted their focus to optimize their assets and to use equipment more effectively, and one of the main areas of the company which has a strong influence on assets is the maintenance department or the employees responsible for maintenance. The main idea behind maintenance is to make the parts and machines ready to do what they are required within the time and sizes allocated and to do it with the fewest amount of resources.

The goal of the paper is introducing the seven quality management principles (QMP) defined in the new edition of ISO 9000:2015 and concerning maintenance. From the process approach perspective, maintenance management is classified as a process supporting production (which is considered the core process). Nevertheless, maintenance management influences (or may influence) not only quantity and cost of production, but also the quality of final products, as well as the safety of people and the environment. As a result, companies benefiting from the so-called good engineering practices treat maintenance not as a cost that should be avoided, but mostly as an activity supporting the efficiency of the applied improvements (including quality management) and a contribution to the company's development.

2. QUALITY MANAGEMENT

Quality management has evolved from inspection, through quality control and quality assurance, to the prediction of product and process failure at the design stage, monitoring predicted Q & R throughout the product life cycle and feedback from customers. This has transformed organizations from an environment with heavy reliance on inspection and hierarchical control, to one employing teamwork, paying attention to customer needs and satisfaction, getting quality right the first time and continuously improving processes (Fig. 1). Consequently, quality practices now encompass a wide range of activities, to include virtually all key design and engineering elements during development, transition to production, production itself as well as logistics, maintenance, etc.

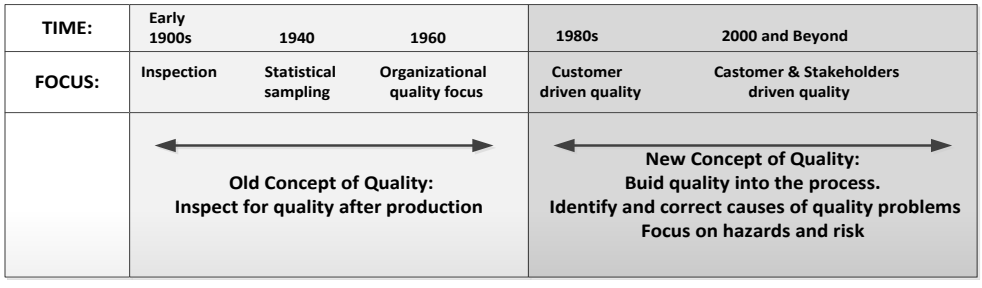

Fig. 1. Timeline showing the differences between old and new concepts of quality

In 2015, the new edition of ISO 9000 standard series was published. One of the important changes introduced in the new edition refers to quality management principles (QMP). The ISO 9000 family of standards are now based on seven quality management principles (Table 1).

Table 1. Quality management principles according ISO 9000:2015

Quality principles	**Description**
Customer focus	Sustained success is achieved when an organization attracts and retains the confidence of customers and other interested parties. Understanding current and future needs of customers and other interested parties contributes to sustained success of the organization.
Leadership	Organizations succeed when leaders establish and maintain the internal environment in which employees can become fully involved in achieving the organization's unified objectives.
Employee engagement	Organizations succeed by retaining competent employees, encouraging continuous enhancement of their knowledge and skills, and empowering them, encouraging engagement and recognizing achievements.
Process approach	The quality management system consists of interrelated processes. Understanding how results are produced by this system enables an organization to optimize the system and its performance.
Improvement	Improvement is essential for an organization to maintain current levels of performance, to react to changes in its internal and external conditions and to create new opportunities.
Evidence-based decision making	Decision making can be a complex process, and it always involves some uncertainty. Facts, evidence and data analysis lead to greater objectivity and confidence in decision making.
Relationship management	Interested parties influence the performance of an organization. Sustained success is more likely to be achieved when the organization manages relationships with all of its interested parties to optimize their impact on its performance.

However, these principles are not a rigid set of requirements. Instead, the relative importance of each principle will vary from organization to organization and can be expected to change over time. This freedom gives an organization flexibility in the way they are implemented and in the way quality management is built to respond to the business needs of a company. However, independently from the flexibility they provide, efficiency of the quality management system depends on their transposition to predefined functional areas and processes of a company.

3. MAINTENANCE MANAGEMENT SYSTEM

Companies are seeking to gain competitive advantage with respect to cost, quality, service and on-time deliveries. The effect of maintenance on these variables has prompted increased attention to maintenance as an integral part of productivity improvement. European standards regarding maintenance defined maintenance management as all the activities of management that determine the maintenance objectives or priorities, strategies and responsibilities and implement them by means such as maintenance planning, maintenance control and supervision and several methods improving, for example, the economic aspects of the organization. The main objectives of maintenance management are: ensuring the plant functionality (availability, reliability, product quality, etc.); ensuring plant and environmental safety; ensuring cost effectiveness in maintenance and effective use of resources (energy and raw materials). The fulfilment of maintenance management objectives is highly dependent on the proper mix of resources and the development of good communication. The uniqueness of tasks and the many different interfaces that exist, require not only good communication skills, but an understanding of the system as an entity and its context. However, the successful implementation of maintenance management requires a thorough understanding not only of system-level requirements, but also of the many organizational interfaces that exist in an enterprise. Good maintenance assumes that maintenance objectives and strategies are not determined in isolation, but are in some way derived from factors such as company policy, manufacturing policy and other potentially conflicting demands and constraints in the company. Maintenance objectives are related to the attainment of production targets (through high availability) at a required quality, and within the constraints of the system conditions and safety.

The term maintenance system refers to the system of interconnected processes which strive to meet customers' and stakeholders' requirements (Fig. 3).

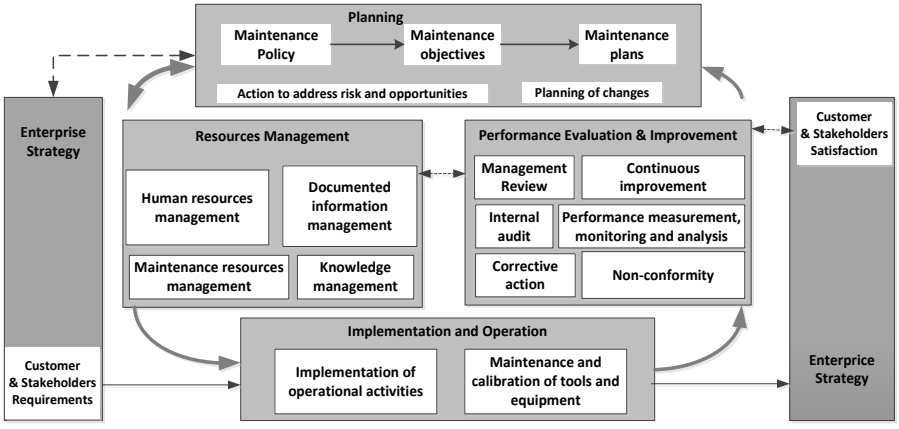

Fig. 3. Maintenance management system

Due to the numerous advantages of maintenance, manufacturing companies are trying to adopt proactive maintenance strategies to support their businesses. Maintenance management supports QMS in creating value for the customer and in achieving efficiency by eliminating losses resulting from equipment failure, set up and adjustments, minor stoppages, process scrap and defects, and reduced yield.

The ISO 9001 standard builds on seven quality management principles. Following these principles will ensure that an organization is set up to consistently create value for its customers and stakeholders. Since maintenance is an inherent element of companies (both manufacturing and service providing) and actively participates in providing customers with value, the quality management principles are also maintenance management principles. The Maintenance Management Framework founded on quality management principles has been designed to assist people who manage maintenance systems to adopt best practices for maintenance management.

4. MAINTENANCE MANAGEMENT FRAMEWORK

4.1. Customer focus

The ISO 9000:2015 standard promotes a narrow definition of the customer as a "person or organization that could or does receive a product or a service that is intended for or required by this person or organization." Examples include: the consumer, client, end-user, retailer, beneficiary and purchaser. According to the standard, a customer can also be internal or external to the organization. To identify customers of a company, it is necessary to consider two perspectives: internal and external. From the external perspective, maintenance activities influence final customers. Maintenance departments of the manufacturing firms will have to be aware of any possible external non-conformity of the product rejected or returned by the customer, which could be a consequence of improperly maintained equipment (Crespo-Marquez, Gupta, 2006, p. 313-326). Shifting tolerances in machine shops is a typical example. The maintenance department will have to be part of product quality audits and be responsible for executing the necessary corrective actions to avoid any related problems (Jasiulewicz-Kaczmarek, 2013, p. 87-98). Hence, requirements of external customers should be identified not only when considering product parameters, but also from the perspective of processes of product realization (Pramod, Pramod, 2015, p. 100-109).

From the internal perspective of a company, maintenance is providing services to various stakeholders within a company. Examples of internal stakeholders of a company include the production department (Tsutsui, Takata, 2012, p. 183-193), logistics department, administration and book-keeping, as well as the owners of the company, etc. Their requirements and expectations are derived from corporate strategy and responsibilities towards customers and other stakeholders of a company.

The quality management principle referred to as "customer focus" indicates not only the need for identifying requirements and expectations of customers, but also analyzing and monitoring their satisfaction. The internal assessment of quality of services provided and efficiency of maintenance is possible with indicators such as MTBF (Mean Time Between Failures**)**, MTTR (Mean Time To Repair**)** and the widely used by numerous companies OEE indicator (OEE rating may be used to compare different sites within an individual business group, and may influence strategic investment and other important). In contrast, the satisfaction of external customers can be evaluated with the number of complaints resulting from the malfunctioning of machines and during technical visits at customers' premises (the so-called customers audits). In many industries customers clearly define their expectations towards the quality of maintenance performance, for example, in terms of the cleanliness of machines or the quality of machine indicators.

4.2. Leadership

Employees are the drivers of maintenance management activities, they are the ones who have their eyes and ears on the process and on the ground realities and hence can detect abnormalities. If employees are drivers, management is the driving force behind these drivers by motivating and cajoling the employees of the organization. Management's task is to instill in the employees a sense of awareness and confidence in dealing with problems and to guide them in learning new techniques to find solutions to these problems.

The role of maintenance leadership is to set new expectations for deploying specific maintenance best practices, explain their benefits to the workforce, and provide resources and training to make the best practices work. The maintenance leader must be self-motivated, organized, trustworthy, empathetic and optimistic. Leadership is also about getting the job done properly through others. Delegating work to subordinates is an important function of management, otherwise nothing ever gets done. Delegation frees up precious time for the manager to focus on high-level, high-value activities. Great leaders get things done by inspiring and empowering others to do great work for them. They foster motivation by giving subordinates autonomy to do the job, by creating a supportive environment, and by giving recognition when the job is done well.

4.3. Employee engagement

Fundamental to the concept of employee engagement is the idea that all employees can make a contribution to the successful functioning and continuous improvement of organizational processes.

Contemporary approaches to maintenance (e.g. Total Productive Maintenance) are based on teamwork and provide a method for the achievement of world-class levels of overall equipment effectiveness through people and not through technology or systems alone (Mugwindiri, Mbohwa, 2013). The teamwork concept means exploiting the abilities and skills of human assets, a collective collaboration between operations and maintenance and the philosophy of empowerment of personnel from the top level to the shop floor and between all functional areas in the organization. The principle of "employee engagement" can be realized in maintenance by the introduction of the so-called autonomous maintenance (AM). The term autonomous doesn't mean performing maintenance in a vacuum or solely by the traditional maintenance department. The main challenge in implementing the AM practice is to change the thinking, habits and culture of the operators, technicians and engineers in taking the responsibility when they are assigned certain tasks. The organization of the AM team consists of small overlapping groups formed across each department in the company, as illustrated in Figure 4.

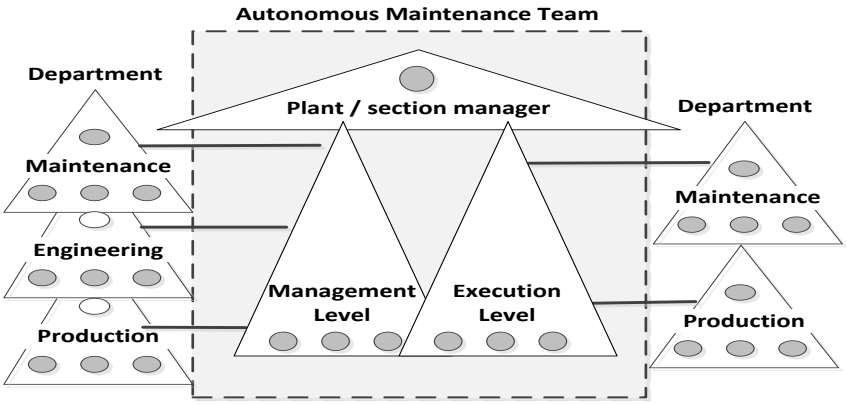

Fig. 4. An overlapping small group organization (Min, Ahmad, Kamaruddin, Azid, 2011, p. 268-297)

The AM team is headed by a senior executive (plant/section manager) that defines the policies, sets targets and coordinates the entire AM process. The body of the AM team is categorized into two levels: the management level and the execution level. The management level involves engineers and production supervisors who monitor the progress of AM activities. The execution level is made up of operators and maintenance technicians. To achieve the best AM practice, both execution and management levels have individual tasks to focus on. The focus of the execution-level personnel is on the maintenance of the equipment based on AM activities, whereas the management level is focused on the improvement process in terms of technology or techniques used in maintaining the equipment.

Cross-functional teams break down organizational barriers, identify problems and are charged with the responsibility of pinpointing problem areas, detailing a course of corrective action and initiating the corrective process.

4.4. Process approach

Process management is an approach to management that views the activities of an organization as a set of processes undertaken to advance organizational goals. The purpose of the process approach is to enhance an organization's effectiveness and efficiency in achieving its defined objectives. A process can be defined as an integrated set of activities that uses various resources to convert inputs to outputs. When adopting the process approach to the maintenance activities, it is equally important to identify each process as it is to characterize it. Characterization usually includes defining the following four universal process affecters (Fig. 5): Method (How?); Human Resources (With Who?); Machines/equipment and materials (With What?); Metrics (With What Key Criteria?).

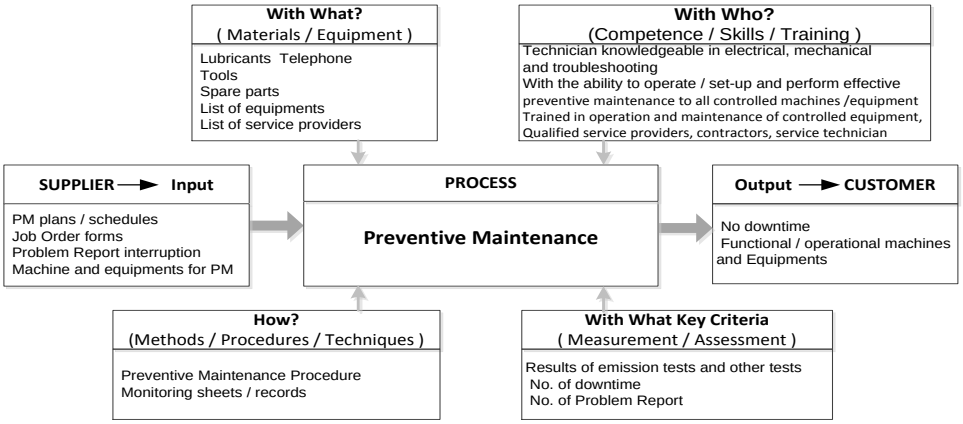

Fig. 5. Preventive Maintenance Process – an example

The next step is sequence definition and identification of interdependencies between the predefined processes. The result is a map of maintenance processes (Fig. 6).

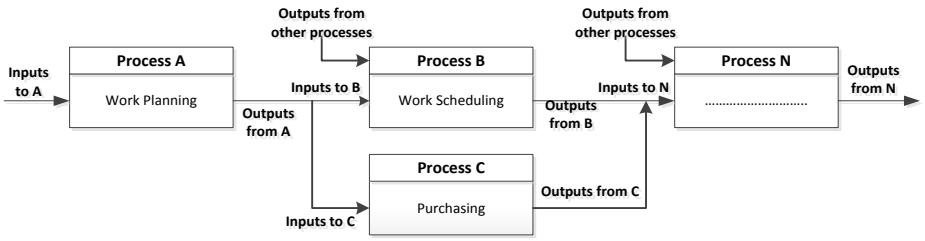

Fig. 6. Maintenance processes

Each process should be measured with one or two metrics that characterize the essentials of its performance (Table 2). Such a metric is called a Key Performance Indicator or KPI. KPIs are very important in the evaluation and assessment of the maintenance process (Muchiri, Pintelon, Gelders, Martin, 2011, p. 295-302).

Table 2. Example of Maintenance Process KPI (Muchiri et. al, 2011, p. 295-302)

Process	Indicators	Description
Work Planning	Planning Intensity / Rate	Planned work/Total work done (%)
	Quality of planning	Percentage of work orders requiring rework due to planning / All work orders
	Planning Responsiveness	Percentage of work orders in planning status for < 5days / All work orders
Work Scheduling	Scheduling Intensity	Scheduled man-hours / Total available man-hours (%)
	Quality of scheduling	Percentage of work orders with delayed execution due to material or man-power
	Schedule realization rate	Work orders with scheduled date earlier or equal to late finish date / All work orders (%)

Maintenance management monitors all maintenance process performance and, based on the criteria or objectives which result from the business strategy, chooses the optimal solutions and leads maintenance processes to their realization.

If we observe a process map in a manufacturing organization, maintenance processes affect the overall product quality, process and organization in the following two ways: by increasing operational readiness, effectiveness and quality of elementary production processes and by improving maintenance processes quality.

4.5. Improvement

Nowadays, a key word in any organization is ‘improvement’. The ISO 9000:2015 standard defined improvement as a set of activities that organizations carry out in order to enhance performance (get better results). Improvement methodologies involve products whose quality has to be improved and whose delivery time has to be shortened, processes whose variances and lead time have to be reduced, infrastructure components whose efficiency and capabilities have to be upgraded, waste to be eliminated or flexibility to be increased.

The Plan Do Check Act cycle is the basis of many management improvement philosophies. It was originally applied to business processes but can be used to implement continuous improvement in almost any process. In relation to maintenance engineering it can be applied to improving maintenance systems, equipment reliability, equipment design, work practices, employee capability, safety and environmental issues related to maintenance practices (Fig. 7).

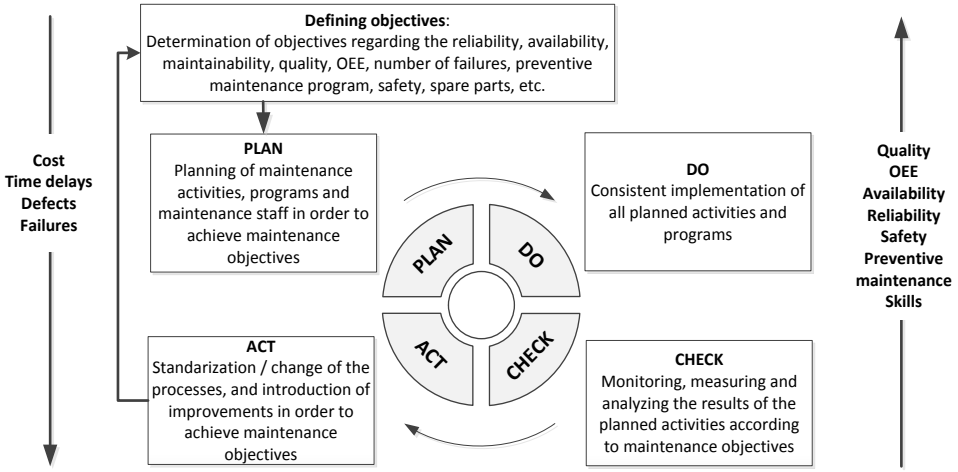

Fig. 7. Conceptual approach for continuous improvement in maintenance (Maletic, Maletic, Gomiscek, 2002, p. 30-41)

Improvements in equipment striving for optimal conditions lead to zero breakdowns, and zero breakdowns lead to zero defects. Striving for a zero defects target leads to a significant cost reduction, which in turn provides the needed cost and quality to protect investments and jobs in the future. For the improvement of maintenance processes both classic quality tools are used, e.g. flow chart, histogram, cause-and-effect diagram, etc. (Fig. 8), and ones originating from the Lean approach such as VSM, Kanban, 5S, SMED and Six–Sigma (Milosavljević, Rall, 2005, p. 93-108). There is an increasing use of simulation programs in improvement as well (Alabdulkarim, Ball, Tiwari, 2012, p. 192-199; Roux, Duvivier, Quesnel, Ramat, 2013, p. 3-12; Zhou, Wang, Huo, Lv, 2010, p. 527-531).

The basic requirement involved in the quality system and the maintenance quality system is the improvement of maintenance efficiency based on a data analysis of the actual behavior of the system, particularly weak point localization and pursuing corrections.

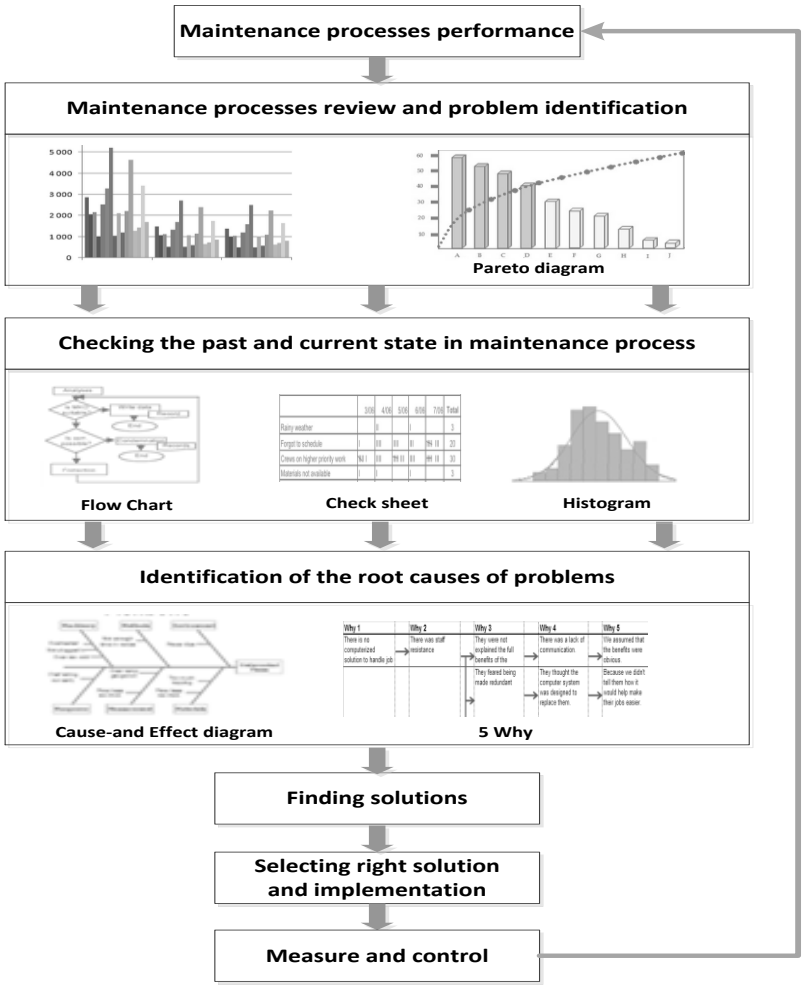

Fig. 8. Quality tools for maintenance process improvement

4.6. Evidence-based decision making

In the past, it was crucial to have the materials and labor available to correct/repair the breakdown. Today, the priority is having the information available. Fast, flexible access to reliable, current, and comprehensive information is vital if planners and managers are to control the maintenance function on the basis of knowledge rather than intuition. Performance monitoring on all levels of maintenance management is a prerequisite for effective decision-making and for this purpose relevant, easily accessible and high quality data is needed. Hence the inevita-

ble trend of computerization of maintenance management processes, that provides a natural increase of routines (both in operators and in maintenance managers), automated scheduling (and many other tasks) and simplifies access to data in general. The demands on MMIT have shifted over the years from being a tool to automate preventive maintenance management, such as task scheduling, plant inventory and stock control or cost and budgeting, to supporting predictive and proactive maintenance by providing real time data processing, effective communication channels and business function integration. New Internet technologies provide new opportunities for information management and making decisions based on facts (Hausladen, I., Bechheim, 2004, p. 46-51; Han, Yang, 2006, 569-580; Jasiulewicz-Kaczmarek, Piechowski, 2012, p. 36-41; Lee, Liao, Lapira, Ni, Li, 2009, p. 1-35; Muller, Marquez, Iung, 2008, p. 1165-1187).

The term e-maintenance appeared at the beginning of the century and is nowadays the most often used in the literature on maintenance. Tsang (2002, p. 7-39) defined e-maintenance as a maintenance strategy where tasks are managed electronically using real time equipment data obtained through digital technologies (i.e. mobile devices, remote sensing, condition monitoring, knowledge engineering, telecommunications and internet technologies (Fig. 9)).

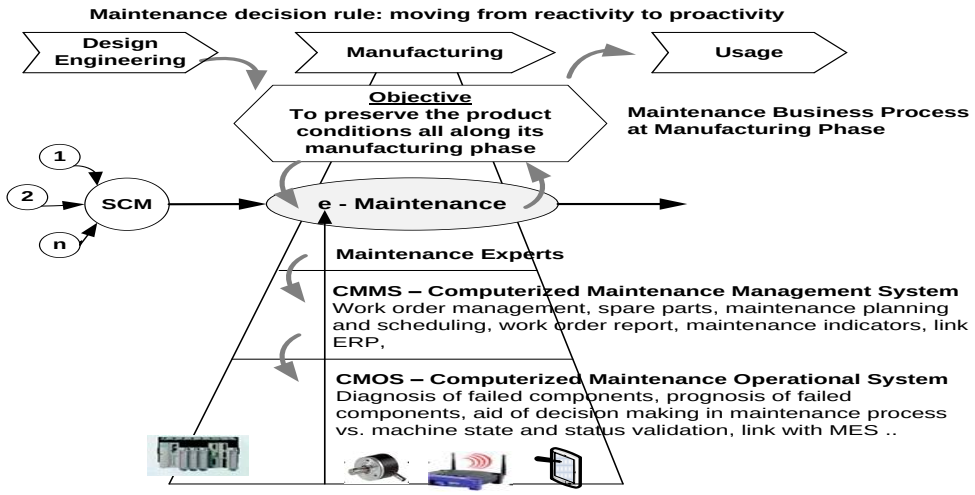

Fig. 9. E-maintenance within the manufacturing phase (Levrat, Iung, Crespo Marquez, 2008, p. 408-429)

E-maintenance seeks to implement maintenance management, wherein maintenance operations, planning and decisions, data and tools to process and act upon them become available anytime, anywhere and to anyone at multiple levels of operation. Lee (Lee, Liao, Lapira, Ni, Li, 2009, p. 1-35) defines future maintenance as: “The Right information to the Right people to do the Right things at the Right

time". This definition corresponds to the challenges of knowledge management in maintenance activities.

4.7. Relationship management

Maintenance influences and is influenced by a wide range of working areas in a plant. Therefore, it participates effectively in company business. Maintenance should be treated as a profit-generating center since it is closely related to a company's internal efficiency (Al-Najjar, 2007, p. 260-273). Traditionally, maintenance's range covers production processes. However, shifting the production paradigm towards sustainable development resulted in shifting the maintenance paradigm towards product lifecycle management. Maintenance is a part of the operational value chain and its goal is creating value for customers (both internal and external). To stress and justify this new approach to maintenance, Takata (Takata at al., 2004, p. 643-656) introduced the term "maintenance value chain". Such a chain should be supported with customer designed processes of maintenance at each stage of a product's lifecycle, considering the involvement of technical staff of a company and employees of other functional areas of a company and external organizational units: designers and manufacturers of equipment, spare parts providers and service providers, etc. (Jasiulewicz-Kaczmarek, 2013, p. 87-98). The greater the importance of external organizational units supporting maintenance, the more technologically advanced technical equipment of a company is. It refers mostly to advanced diagnostic and prognostic technologies (i.e. e-technologies which are the elements of the e-maintenance domain). Hence, the development and integration of maintenance from a product's lifecycle perspective requires and will require many interfaces with other systems, both internal and external, and cooperation between maintenance and its stakeholders. Stakeholders frame the maintenance department and determine the needs and constraints on maintenance processes. Stakeholders are therefore key to all maintenance management processes, plans and decisions. As reinforced in ISO 9000:2015, the term stakeholder or "interested party" refers to an individual or organization that can affect or be affected by an organizational decision or activity. Stakeholders bring their contribution and set requirements, expecting the results that satisfy their requirements. Contributions brought by the stakeholders include capital, knowledge, skills, materials and services provided for maintenance, etc. Naturally, stakeholders need some motivation to make their contribution and the motivation is awards such as money, power, status, safety, etc.

With respect to maintenance management, stakeholders within an organization can be internal or external (Fig. 10).

Examples of internal stakeholders include owners, maintenance staff, as well as production, logistics, book keeping staff, etc., while external customers are: spare parts providers, engineers and producers of machines and devices, etc. The ability to exchange information and develop relations with stakeholders enables the identification of their needs and expectations. Knowing and understanding provides op-

portunities for adjustments, setting common goals and businesses and developing relations based on knowledge and providing sustainable results.

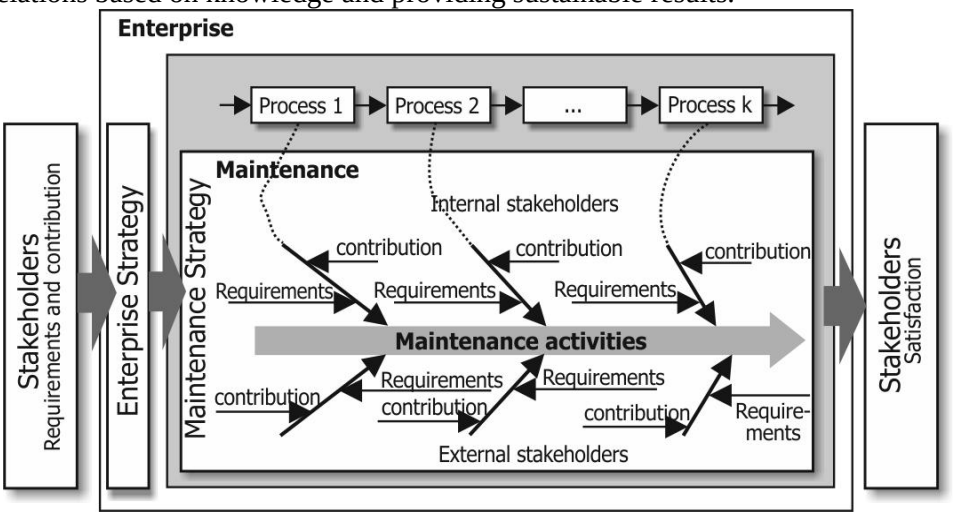

Fig. 10. Internal and external maintenance stakeholders (Jasiulewicz-Kaczmarek, 2013, p. 87-98)

5. CONCLUSION

A more profound analysis of the place and the role of maintenance activities inside the industrial companies reveals the fact that this activity is directly or indirectly involved in achieving the four operational management objectives: zero breakdown, zero failures, zero stock and zero delays. It is unquestionable that, for maintenance to contribute effectively to the success of an organization, top management should start to see maintenance as a strategic area of the entire business system and no longer as an area simply generating costs. Maintenance should be seen as an area that adds value to the work processes and to the business. For the organization which want to run their business in a holistic and strategic view, it is clear that they need to deeper integrate the maintenance management system to the quality management system. The Maintenance Management Framework based on seven qualities of management principles can help an organization to: increase output with the same assets, reduce the need for capital replacement and improve performance, cost, productivity and safety.

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ZASADY ZARZĄDZANIA JAKOŚCIĄ WEDŁUG NORMY ISO 9000:2015 JAKO RAMY ZARZĄDZANIA SYSTEMEM UTRZYMANIA RUCHU

Streszczenie

Przedsiębiorstwa starają się uzyskać przewagę konkurencyjną poprzez zwrócenie uwagi na koszty, jakość i terminowość dostaw. Wpływ utrzymania ruchu na te zmienne skłania zarządzających do zwrócenia uwagi na procesy utrzymania ruchu i uznania tego obszaru jako integralnej części doskonalenie produktywności przedsiębiorstwa. Ramy zarządzania utrzymaniem ruchu określone są poprzez strategie, przewodniki i narzędzia niezbędne dla działu utrzymania ruchu, aby osiągnąć jakość, efektywność i skuteczność w wykonywaniu swoich obowiązków. W przedsiębiorstwie, które utrzymuje system zarządzania jakością, ramy te powinny być oparte na siedmiu zasadach zarządzania jakością zgodnie z normą ISO 9000: 2015.

Słowa kluczowe: zarządzanie utrzymaniem ruchu, zasady zarządzania jakością, ISO 9000:2015