



APPLICATIONS AND CASE STUDIES

Maintenance performance measurement (MPM): issues and challenges

MPM: issues and challenges

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Abstract

Purpose – The purpose of this study is to identify various issues and challenges associated with development and implementation of a maintenance performance measurement (MPM) system.

Design/methodology/approach – An analytical approach is adopted to identify the issues and challenges associated with MPM.

Findings – The study finds that for successful implementation of MPM all employees should be involved and all relevant issues need to be considered. Furthermore, the traditional overall equipment effectiveness (OEE) used by the companies is inadequate, as it only measures the internal effectiveness. For measuring the total maintenance effectiveness both internal and external effectiveness should be considered.

Practical implications – What cannot be measured cannot be managed effectively. To manage maintenance process operating managers and asset owners need to measure the contribution of maintenance towards their business goals. This paper discusses issues and challenges associated with MPM system, there by helping the managers to take care of the pitfalls of the MPM system and advocates that managers should focus on measuring the total effectiveness of maintenance process.

Originality/value – The paper presents a concept of total maintenance effectiveness with focus on both internal and external effectiveness, and integration of the hierarchical levels and multi-criteria maintenance performance indicators of MPM system.

Keywords Maintenance, Performance measures, Employee involvement

Paper type Research paper

Introduction and background

Maintenance is defined as the combination of all the technical and administrative actions, including supervision, intended to retain an item, or restore it to a state in which it can perform a required function (International Electrotechnical Commission, 2006). Maintenance provides critical support for heavy and capital-intensive industry by keeping machinery and equipment in a safe operating condition. Today it is accepted that maintenance is a key function in sustaining long-term profitability for an organization (Al-Sultan and Duffuaa, 1995).

Maintenance performance measurement (MPM) has received a great amount of attention from researchers and practitioners in recent years due to a paradigm shift in maintenance, as explained in Figure 1. Prior to the early 1900s, maintenance was considered as a necessary evil. Technology was not in a state of advanced development, there was no alternative for avoiding failure, and the general attitude to maintenance was, "It costs what it costs." With the advent of technological changes



and after the Second World War, maintenance came to be considered as an important support function for production and manufacturing. During 1950-1980, with the advent of techniques like preventive maintenance and condition monitoring, the maintenance cost perception changed to: "It can be planned and controlled." Today maintenance is considered as an integral part of the business process and it is perceived as: "It creates additional value" (Liyanage and Kumar, 2003). The measurement of maintenance performance has also become an essential requirement for the industry of today.

The efficiency and effectiveness of the maintenance system play a pivotal role in the organization's success and survivability. Therefore, the system's performance needs to be measured using a performance measurement (PM) technique. According to Bititci *et al.* (1997), performance management is defined as the process by which a company manages its performance. It should be "in line with its corporate and functional strategies and objectives". Neely *et al.* (1995) defined PM as the process of quantifying the efficiency and effectiveness of action.

A PM system is defined as the set of metrics used to quantify the efficiency and effectiveness of actions. For many asset-intensive industries, the maintenance costs are a significant portion of the operational cost. In addition, breakdowns and downtime have an impact on the plant capacity, product quality, and cost of production, as well as health, safety and the environment.

This paper analyses the issues and challenges associated with the different facets of MPM and outlines the scope of a multi-criteria hierarchical approach to maintenance performance measurements.

The following is an outline of this paper. The first section provides the background and a brief introduction to maintenance performance measurements. The next section provides an overview of MPM techniques and maintenance performance indicators (MPIs). The following section outlines the issues involved in MPM for any complex organization. Challenges associated with the development of MPIs and practical applications in the real world are discussed in the penultimate section. The final section provides a summary of the paper and discusses the scope of future work.

An overview of maintenance performance system (MPM)

In the past two decades, PM has received a great amount of attention from researchers and practitioners. Major issues related to this field concern what to measure and how to measure it (Neely, 1999) in a practically feasible and cost-effective way. Improper implementation and management of measurement system development aiming to use new measures to reflect new priorities often lead to ineffective results. This is due to the failure of the organization to discard measures reflecting old priorities, uncorrelated and inconsistent indicators and inadequate measurement techniques (Meyer and Gupta, 1994). Measurement gives the status of the variable, compares the data with

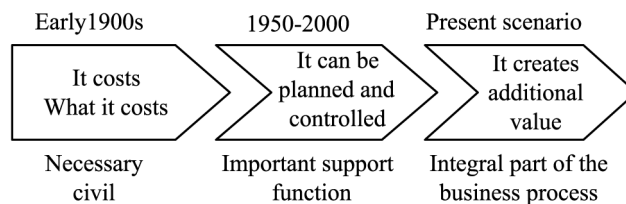


Figure 1.
Paradigm shift in
maintenance

target or standard data and points out what actions should be taken and where they should be taken as corrective and preventive measures. This is extremely difficult without adequate data to develop models for supporting the decision-making process (Wealleans, 2000). The characteristics of performance measures include relevance, interpretability, timeliness, reliability and validity (Al-Turki and Duffuaa, 2003). An operational PM system acts like an early-warning system.

Several frameworks have been developed for measuring performance over the years. Till 1980, the PM was based on mostly on financial measures. The balanced scorecard, with its four perspectives, focuses on financial aspects, customers, internal processes, and innovation and learning (Kaplan and Norton, 1992). It looks into both tangible (financial) and intangible aspects of the business process. Subsequently, various researchers have developed frameworks considering non-financial measurements and intangible assets to achieve competitive advantages (Kaplan and Norton, 2001). It is observed that companies using an integrated balanced PM system perform better than those that do not measure their performance (Kennerly and Neely, 2003; Lingle and Schiemann, 1996). The issues and challenges associated with MPM system concern relevance, interpretability, timeliness, reliability, validity, cost and time effectiveness, and ease of implementation, updating and maintenance for regular use by stakeholders at various levels.

MPM

Maintenance works as an important support function in business with significant investment in physical assets and plays an important role in achieving organizational goals (Tsang, 2002). Cross (1988) reported that, in the UK manufacturing industry, maintenance spending ranges from 12-23 percent of the total factory operating costs. In refineries, the maintenance and operations departments are very large and each department often consists of up to 30 percent of the total staffing (Dekker, 1996). A study by the Swedish mining industry shows that the cost of maintenance in a highly mechanized mine can be 40-60 percent of the operating cost (Danielson, 1987). Some of the important factors behind demands on maintenance performance measures are:

- *Measuring value created by the maintenance.* The most important reason for implementing maintenance performance system is to measure the value created by maintenance process. As a manager, one must know that what is being done is what is needed by the business process, and if the maintenance output is not contributing/creating any value for the business, it needs to be restructured. This brings the focus on doing right things keeping in view the business goal of the company.
- *Justifying investment.* The second basic reason for measuring maintenance effectiveness is to justify the organization's investment made in maintenance organization; not so much as to whether you are doing the right thing, but whether the investment they are making is producing a return on the resources that are being consumed.
- *Revising resource allocations.* The third basic purpose for measures of effectiveness is to determine if additional investment is required and to justify the investment if, management needs more of what you are doing. Alternatively, such measurement of activities also permit you to determine whether you need to

change what you are doing or how you are doing it more effectively by using the resources allocated.

- *Health safety and environmental (HSE) issues.* The fourth reason can be to understand the contribution of maintenance towards HSE issues. A bad maintenance performance can lead to accidents (safety issue) and pollutions (health hazards and environmental issues), besides encouraging an unhealthy work culture and environment.
- *Focus on knowledge management.* Many companies especially those involved in delivery of maintenance and product support services are focused on effective management of knowledge in their companies. Furthermore, technology is ever changing and is changing faster in the new millennium. This has brought in new sensors and embedded technology, information and communication technology (ICT) and condition-based inspection technology such as vibration, spectroscopy, thermography and others, which is replacing preventive maintenance with predictive maintenance. This necessitates a systematic approach for the knowledge growth in the field of specialization.
- *Adapting to new trends in operation and maintenance strategy.* New operating and maintenance strategy is adopted and followed by industries in quick response to market demand, for the reduction of production loss and process waste. MPM measures the value created by the maintenance.
- *Organizational structural changes.* Today organizations are trying to adopt a flat and compact organizational structure, a virtual work organization, and empowered, self-managing, knowledge management work teams and workstations. All these innovations need to integrate the MPM system to provide a rewarding return for maintenance services.

MPI

MPIs are utilized to evaluate the effectiveness of maintenance carried out (Wireman, 1998). An indicator is a product of several metrics (measures). A performance indicator is a measure capable of generating a quantified value to indicate the level of performance, taking into account single or multiple aspects. The selection of MPIs depends on the way in which the MPM is developed. MPIs could be used for financial reports, for monitoring the performance of employees, customer satisfaction, the HSE rating, and overall equipment effectiveness (OEE), as well as many other applications. When designing MPIs, it is important to relate them to both the process inputs and the process outputs. If this is carried out properly, then MPIs can provide or identify resource allocation and control, problem areas, the maintenance contribution, benchmarking, personnel performance, and the contribution to maintenance and overall business objectives (Kumar and Ellingsen, 2000).

Issues and challenges involved in MPM for any organization

Maintenance is an important issue for any organization today. The PM system needs to be aligned to organizational strategy (Kaplan and Norton, 2001; Eccles, 1991; Murthy *et al.*, 2002). Each successful company measures its maintenance performance in order to remain competitive and cost effective in business. Understanding the need for MPM in the business and its work process is critical for the development and successful

implementation of the MPM. An important objective of the measurement system should be to bridge the gap and establish the relationship between the internal measures (causes) and the external measures (effects) (Jonsson and Lesshammar, 1999).

Maintenance process mapping

It is essential to understand the maintenance process in detail, before going to study the issues involved in MPM system for any complex organization, so that implementation of the MPM system is possible without difficulty. The maintenance process starts with the maintenance objectives and strategy, which are derived from the corporate vision, goal and objectives based on the stakeholders' expectations. Based on the maintenance objectives, maintenance policy, organization, resources and capabilities, a maintenance program needs to be developed. This program is broken down into different types of maintenance tasks. The execution of the maintenance tasks is undertaken at specified times and locations as per the maintenance plan. Examples of maintenance tasks are repair, replacement, adjustment, lubrication, modification and inspection. The management needs to understand the importance of maintenance and match the plan to the vision, goal and objectives of the organization. However, in real life there is a mismatch between the expectations of external and internal stakeholders and the capability, between the organizational goals and the objectives of and resources allocated for maintenance planning, and between the execution and the reporting through data recording and analysis. There is a need to map the maintenance process and identify the gap between the maintenance planning and execution.

Appropriate logistic support is vital for both maintenance planning and maintenance execution. Such support includes the availability of spare parts, consumable materials, tools, instruction manuals, documents, etc. Logistic support acts as a performance driver that motivates and enhances the degree of maintenance performance. The non-availability of personnel, spares and consumable materials needs to be looked into, because otherwise it can act as a performance killer. Human factors such as unskilled and unwilling personnel act as a de-motivating factor that prevents the achievement of the desired results. Therefore, one must ensure the human resources and training necessary for the maintenance planning and execution team. Problems in the reporting system are a major issue for any maintenance organization. It is necessary to understand the organizational need and then to procure or develop a system. The personnel using the system need to be trained. Analysis of data plays an important role. It is equally important that the management should be involved in the whole process and there should be commitment and support from the top management.

The issues related to MPM are determined by answering the questions such as: "What indicators are relevant to the business and related to maintenance?"; "How the indicators are related to one another and take care of the stakeholders' requirements?"; "Are the MPis measurable objectively and how do the MPis evaluate the efficiency and effectiveness of the organization?"; "Are the MPis challenging and yet attainable?"; "Are the MPis linked to the benchmarks or milestones quantitatively/qualitatively?"; "How does one take decisions on the basis of the indicators?"; and "What are the corrective and preventive measures and when and how does one update the MPis?".

Some of the basic questions require deliberation and critical examination while designing such MPM system. The questions that form the basic challenges associated with the development and implementation of MPM system are given in Figure 2.

The MPIs need to be developed based on the answers to the above questions. The relevant data need to be recorded and analyzed on a regular basis and used for monitoring, control of maintenance and related activities, and decision making for preventive and corrective actions. The MPIs could be time- and target-based, giving a positive or negative indication. An MPI could be trend-based in some cases. If it is positive or steady, meaning that everything is working well, then the action is “do nothing”. If it shows a negative trend and has crossed the lower limit of the target, then the decision is to act immediately. The value of the MPI, when falls within the limits (as set by the decision maker), then the decision is “wait and see”. Different types of graphs and figures could be used for indicating the health state of the technical system using different color codes for “excellent”, “satisfactory”, “improvement required” and “unsatisfactory performance level”. There could be other visualization techniques using bar charts or other graphical tools for monitoring MPIs. The issues related to the development and implementations of MPM are:

- *Strategy.* How does one assess and respond to stakeholders’ (internal and external) needs? How does one translate the corporate goal and strategy into targets and goals at the operational level (converting a subjective vision into objective goals)? How does one integrate the results and outcomes from the operational level to develop MPIs at the corporate level (converting objective outcomes into strategic MPIs and linking them to strategic goals and targets)? How to support innovation and training for the employees to facilitate an MPM-oriented culture?
- *Organizational issues.* How to align the MPM system with the corporate strategy? Why there is a need to develop a reliable and meaningful MPM system? What should be measured, why it should be measured, how it should be measured, when it should be measured and what should be reported; when, how and to whom? How to establish accountability at various levels? How to improve communication within and outside the organization on issues related to information and decision making?
- *How to measure?* How to select the right MPIs for measuring MPM? How to collect relevant data and analyze? How to use MPM reports for preventive and predictive decisions?
- *Sustainability.* How to apply MPM strategy properly for improvement? How to develop an MPM culture across the organization? How to implement of a right internal and external communication system supporting MPM? How to review

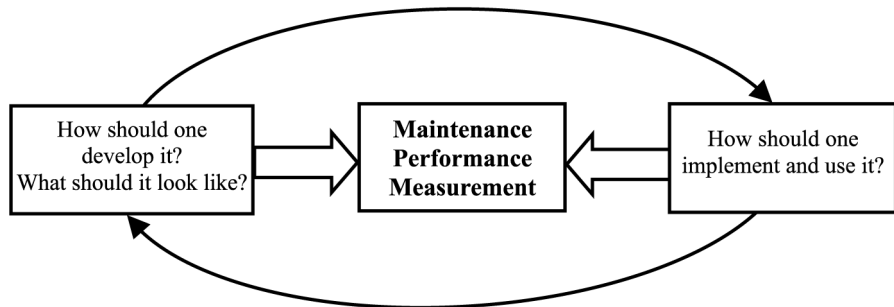


Figure 2.
Questions involved in the development and implementation of MPM

and modify the MPM strategy and system at regular intervals? How to develop and build trust in MPIs and MPM system at various levels.

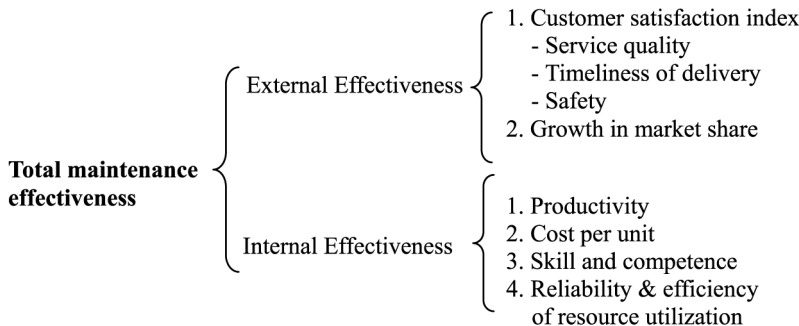
The SMART test is frequently used to provide a quick reference to determine the quality of the performance metrics (Department of Energy, 2002). SMART stands for:

- *S.* Specific – clear and focused to avoid misinterpretation. Should include measure assumptions and definitions and be easily interpreted, e.g. maintenance cost/ton.
- *M.* Measurable – can be quantified and compared to other data. It should allow meaningful statistical analysis. Avoid “yes/no” measures except in limited cases, such as start-up or systems-in-place situations.
- *A.* Attainable – achievable, reasonable, and credible under the conditions expected.
- *R.* Realistic – fits into the organization’s constraints and is cost-effective.
- *T.* Timely – obtainable within the time frame given.

The MPM system for the total maintenance effectiveness

Often an MPM system implemented in companies’ deals with internal effectiveness of the maintenance system that is all these measures are focused on measuring the productivity in terms of maintenance cost per unit or maintenance productivity in terms of work order executed per unit of time. The development and implementation of an MPM system should normally be focused on measuring total maintenance effectiveness, reflecting the contribution of maintenance process to the companies’ business goal. It is difficult to develop an MPM that incorporates metrics for measuring the external effectiveness. Currently, the most challenging issue for the maintenance managers is to develop and implement a system that measures both the external and internal effectiveness of maintenance process.

The total maintenance effectiveness based on an organizational effectiveness model considering both the external effectiveness and the internal effectiveness is given in Figure 3. The concept of total maintenance effectiveness envelops the entire organization. The total effectiveness is a product of the internal effectiveness measured through internal efficiency, which is characterized by issues related to effective and efficient use of resources. These facilitate the delivery of the maintenance and related



$$\text{Total maintenance effectiveness} = \text{Internal effectiveness} \times \text{External effectiveness}$$

Figure 3. Total effectiveness based on an organizational effectiveness model

services in the most effective way characterized by the engineering and business processes related to the planning and resource utilization; and external effectiveness characterized by customer satisfaction, growth in market share, etc. (Bruzelius and Skärvad, 2004; Ahlmann, 2002). The performance measures for internal effectiveness is concerned with doing things in right way and can be measured in terms of cost effectiveness (maintenance costs per unit produced), productivity (number of work orders completed per unit time) etc. and deals with managing resources to produce services as per specifications.

The performance measures for external effectiveness deals with measures that have long term effect on companies profitability and is characterized by delivering right type of maintenance services the customer wants. From customers' perspective quality and timeliness of service delivery is often of utmost importance. Here the concept of delivering is not only the services required by customers, but also helping them in their other business process related to their own services. Such an attitude often helps in market growth, innovative service and service delivery; and capturing or creating new markets.

For measuring the total maintenance effectiveness, a balanced, multi-criteria and hierarchical MPM system is considered to be effective, which considers both the external effectiveness and internal efficiency (Parida *et al.*, 2005). There is a need to workout an overall total maintenance effectiveness considering all the factors and criteria. In general measures for total maintenance effectiveness must be combined with process owners' capability to change maintenance and service processes and adapts to new technology and work practices without any major involvement of resources and at right time.

Empirical example of total maintenance effectiveness

Traditionally, the concept of OEE, used by manufacturing company to measure the effectiveness of their organization is inadequate as it only measures the internal effectiveness of maintenance or organization. For example, if the OEE level of an organization is high, then, the product of availability, performance speed, resource utilization and quality will be high, reflecting a higher internal efficiency. But, if the external effectiveness, which is characterized by a customer satisfaction index, such as service quality (of repair/modification and promptness of response), timeliness of delivery and safety, is low; then, the total maintenance effectiveness will be low. Internal effectiveness is expressed in terms of internal efficiency, which is reflected in terms of manufacturing of products in right way, in right quality and quantity (Ahlmann, 2002). Internal effectiveness for manufacturing company is generally expressed in terms of OEE, which is a product of availability, performance speed and product quality. For service industry, the internal effectiveness is measured differently as given in the empirical example. External effectiveness is a measure of business performance reflecting the client's judgement of satisfaction, service quality, future purchase intentions and willingness to recommend the service firm to others (Paulin *et al.*, 1999).

To give an empirical example, for a multi-national utility company in the service sector, the internal effectiveness of maintenance process measured through internal efficiency such as average interruption period per year, number of all unsuccessful starting up of plant, unwanted water spillage, and number of work order scheduled to

number of work order received is calculated to be 90 percent. External effectiveness (delivering the right product/service to customers on demand in right time) is 58.7 percent, which is measured through customer satisfaction index considering all customer-related factors, such as customer retention, customer satisfaction and growth (SKI, 2005). The total maintenance effectiveness of the company is given in Table I. We assume that this index also in some way reflects the external maintenance effectiveness.

For an internationally reputed mineral processing plant producing world-class iron ore pellets, the internal efficiency, measured through availability, performance speed and production quality (overall equipment effectiveness) is 72 percent. The external effectiveness of this plant; measured through customer satisfaction, which considers; timely product and service delivery, quantity and quality of the product delivered, besides customer retention and growth. Issues like; how many times ship has to wait at the harbor due to plant production breakdown and what is the customer retention, and market growth; are considered for measuring external effectiveness. In the past three years, there are no customer complaints with regard to timely delivery and product quality. With an external effectiveness of 99 percent, the total maintenance effectiveness of the plant is given in Table II.

These two empirical examples indicate that for high total maintenance effectiveness, both the internal and external effectiveness should be high.

Integration of the maintenance from shop floor to strategic level

The maintenance strategy should be derived from and linked to the corporate strategy. In order to accomplish the top-level objectives of the espoused maintenance strategy, these objectives need to be cascaded into team and individual goals. The adoption of fair processes is the key to successful alignment of these goals. It helps to harness the energy and creativity of committed managers and employees to drive the desired organizational transformations (Tsang, 1998). For a process industry or production system, the hierarchy is composed of the factory, process unit and component levels. The hierarchy corresponds to the traditional organizational levels of the top, middle and shop floor levels. Murthy *et al.* (2002) mention that maintenance management needs to be carried out in both strategic and operational contexts and the organizational structure is generally structured into three levels. However, there are some organizations that may require more than three hierarchical levels to suit their complex organizational structure. The MPM system needs to be linked to the functional and hierarchical levels for the meaningful understanding and effective monitoring and control of managerial decisions (Parida *et al.*, 2005). Defining the

Internal efficiency	External effectiveness	Total maintenance effectiveness
0.90	0.58	0.52

Table I.

Internal efficiency	External effectiveness	Total maintenance effectiveness
0.72	0.99	0.71

Table II.

measures and the actual measurements for monitoring and control constitute an extremely complex task for large organizations. The complexity of MPM is further increased for multiple criteria objectives.

From the hierarchical point of view, the top level considers corporate or strategic issues on the basis of soft or perceptual measures from stakeholders. In a way the strategic level is subjective, as it is linked to the vision and long-term goals, though the subjectivity decreases down through the levels, with the highest objectivity existing at the functional level. The second level considers tactical issues such as financial and non-financial aspects both from the effectiveness and the efficiency point of view. This layer is represented by the senior or middle management, depending on the number of levels of the organization in question. If an organization has four hierarchical levels, then the second level represents the senior managerial level and the third level represents the managerial/supervisory level. The bottom level is represented by the functional personnel and includes the shop floor engineers and operators. The corporate or business objective at the strategic level needs to be communicated down through the levels of the organization, in such a way that this objective is translated into the language and meaning appropriate for the tactical or functional level of the hierarchy.

The maintenance objectives and strategy, as derived from the stakeholders' requirements and corporate objectives and strategy, considering the total effectiveness, front-end processes and back-end processes, integrating the different hierarchical levels both from top-down and bottom-up manner involving the employees at all levels. At the functional level, the objectives are converted to specific measuring criteria. It is essential that all the employees speak the same language throughout the entire organization.

An MPM system can be divided into three phases: the design of the performance measures, the implementation of the performance measures, and the use of the performance measures to carry out analysis/reviewing (Pun and White, 1996). The feedback from the reviewing to the system design keeps it valid in a dynamic environment.

Both the identification of appropriate measures and explicit consideration of trade-offs between them can be significantly assisted if the relationships among measures are mapped and understood (Santos *et al.*, 2002) well in advance. Therefore, the development of the MPM system requires the formation of a PM team which should include stakeholders at various levels and the management and which should carry out preparatory work for this development work. The PM team should have clear and specified objectives, a time plan and a plan of action as pre-requisites.

Multi-criteria MPM system

The MPM system needs to facilitate and support the management leadership for timely and accurate decision making. The system should provide a solution for performance measurements linking directly with the organizational strategy and by considering both non-financial and financial indicators. At the same time, the system should be flexible, so as to change with time as and when required. The MPM system should have transparency and enable accountability for all the hierarchical levels. From the application and usage point of view, the MPM system should be technology and user-friendly and should be easily facilitated by training the relevant personnel. MPIS

can be classified into seven categories (Parida *et al.*, 2005) and are linked to each other for providing total maintenance effectiveness: MPM: issues and challenges

- (1) customer satisfaction related indicators;
- (2) cost-related indicators;
- (3) equipment-related indicators;
- (4) maintenance task-related indicators;
- (5) learning and growth-related indicators;
- (6) health safety and environment (HSE); and
- (7) employee satisfaction-related indicators.

Before implementation, the MPIs need to be tested for; reliability; that is, the ability to provide the correct measures consistently over time, and, for, validity, which is the ability to measure what they are supposed to measure.

Implementation of the MPM system

Implementation of the developed MPM system for an organization is very critical. Neely *et al.* (2000) mention fear, politics and subversion as issues involved in this phase. Ineffective use of information to improve operation without support of appropriate tools and lack of active management commitment and involvement is another critical issue, without which an MPM system can not be effective or implemented fully (Santos *et al.*, 2002). Dumond (1994), mentions lack of communication and dissemination of results as important issues. The alignment of PM with the strategic objectives of the organization at the design and development of MPM system is critical for achieving effectiveness of the implementation phase (Kaplan and Norton, 1992; Lynch and Cross, 1991).

Prior to a pilot project studying the MPM system, it is desired that the relevant personnel of the organization should be trained in advance to create an awareness of MPM, the need for MPM and the benefits of MPM. A system of continuous monitoring, control and feedback needs to be institutionalized for the continuous improvement and successful implementation of the MPM system.

Conclusion

In this paper, the need for maintenance PM is analyzed and a brief review of existing maintenance performance measures is provided. Measurement of maintenance is a complex issue, and when it comes measuring the external effectiveness, it becomes more difficult in linking the objective outcome at operational level to corporate strategic level. The issues and challenges involved in developing and implementing an effective MPM system is discussed. MPM model can facilitate the correct estimation of the contribution of maintenance to the business goal. There is enough scope for future work in this research area. The authors are currently working on development of a multi-criteria hierarchical model for maintenance PM with two industries and the results will be published in the future.

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