Maintenance Performance Measurement

Methods, Tools and Applications

For many asset-intensive industries, the costs of maintenance 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. To improve the maintenance function, in any context, it is essential that its performance both from external (the impact on customers' business process that is the value generated for the customer) and internal (the work processes in maintenance itself and its integration with in the organization) are measured. This article analyses the issues and challenges associated with the different facets of maintenance performance measurement (MPM) and presents tools and methods to measure the performance of maintenance and illustrates their applicability through simple examples.

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Today, maintenance is considered as an integral part of the business process and it is perceived as: "It creates added value in the business process". With this change in industries' strategic paradigm, managers and engineers are getting more and more interested in measuring the contribution of maintenance towards total business goals. In addition, the increased focus of senior industry managers and engineers "on sustainability and energy saving" has brought the issue of effective an efficient operation and maintenance of industrial systems to the centre stage.

MPM should be in line with organization's corporate and functional strategies and objectives. Therefore, the maintenance performance of an engineering asset needs to be assessed in order to be managed effectively and efficiently. Besides, breakdowns of plant and machineries and downtime, have an impact on the plant capacity, product quality, and cost of production, as well as health, safety and the environment. Thus, MPM is receiving more and more attention from researchers and practitioners in the recent years.

Maintenance Performance Measurement (MPM)

MPM system is defined as the set of metrics used to quantify the efficiency and effectiveness of maintenance actions. Since last two decades, practitioners and researchers have been using Performance Measurement (PM) extensively for assessing the performance of engineering assets. The literature in PM developed through two phases; first phase of cost accounting orientation phase commenced in late 1880s and; the second phase commenced after 1980, dealing with balanced and integrated view of PM. The first phase of financial focus was criticized for short term measures and its failure to measure and integrate all the factors which are critical to the success of the business.

Some of the important factors behind demands on measuring the performance of maintenance are:

a) Measuring value created by the maintenance.
b) Justifying investment.
c) Revising resource allocations.
d) Health safety and environmental (HSE) issues.
e) Focus on knowledge management.

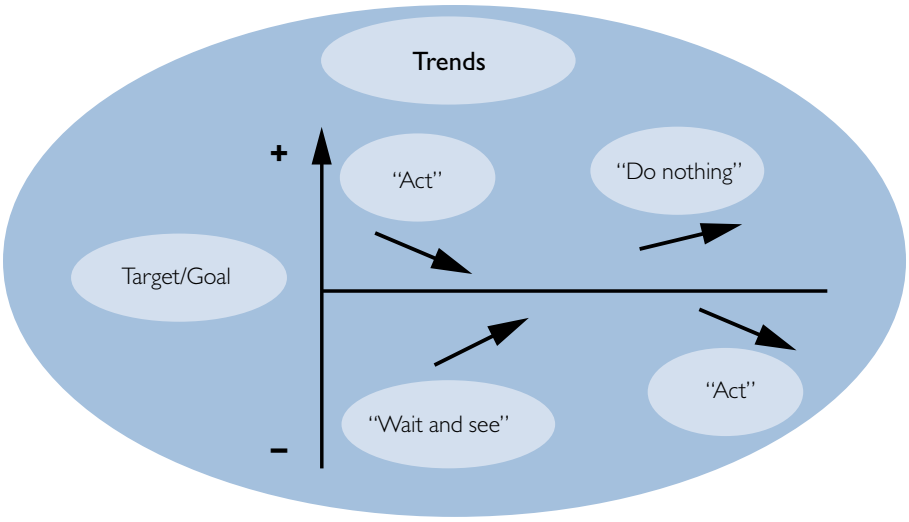

FIGURE 1. *Trend indicators can be a basis for decision making and resource allocation.*

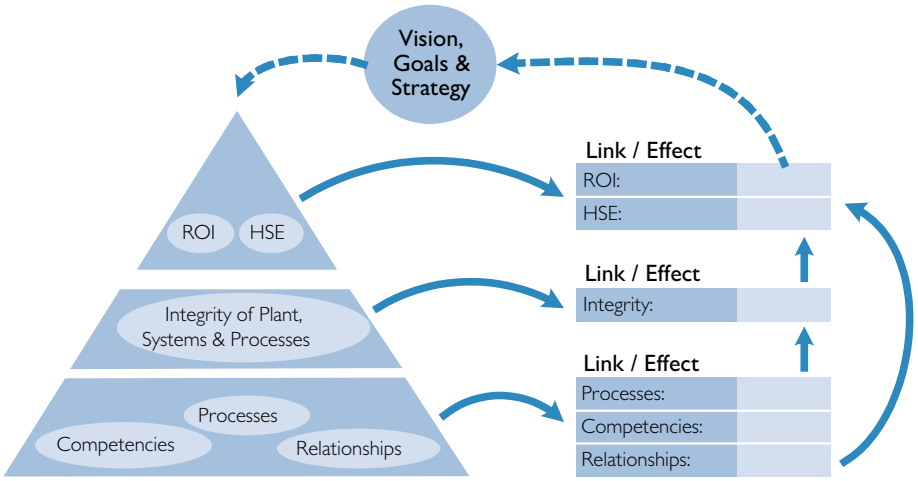

FIGURE 2. *Maintenance balanced score card linking operation and maintenance to corporate goal and vision.*

f) Adapting to new trends in operation and maintenance strategy.
g) Organizational structural changes.

Issues and Challenges in MPM

It is essential to understand the maintenance process (process mapping) 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, goals 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 planning and scheduling. Examples of maintenance tasks are repair, replacement, adjustment, lubrication, modification and inspection.

The issues related to the development and implementations of MPM are discussed below.

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 Key Performance Indicators (KPIs) at the corporate level (converting objective outcomes into strategic KPIs and linking those 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 Maintenance Performance Indicators (MPIs) for measuring MPM and finding trends for decision making as shown in **FIGURE 1.** It is important to focus on trends rather than on individual vales. How to collect relevant data and analyze it? How to use MPM reports for preventive and predictive decisions?

SUSTAINABILITY

How to apply MPM strategy properly for improvement? How to implement right internal and external communication system supporting MPM? How to review and modify the MPM strategy and system at regular intervals? How to sustain the MPM system?

MPM Methods

MPM of an engineering asset is required for continuous improvement and in identifying priorities. MPM can be subdivided into five main components: productivity, organization, work efficiency, cost and quality, together with some overall measurements. Different researchers have indicated different criteria for measuring maintenance performance, like; maintenance process, and maintenance task related etc. In an MPM system, there are a number of criteria or goal functions which need to be considered from different stake holders' view and these MPIs needed to be integrated from operational level to the tactical and strategic hierarchical levels.

In our MPM framework for engineering asset, Kaplan and Norton's (1992) four perspectives of balanced scorecard are considered, besides the engineering asset criteria. Kaplan and Norton's (1992) balanced scorecard considered both financial and non-financial perspectives and took lead in these developments. Later on, various researchers have developed frameworks considering non-financial measurements and intangible assets to achieve competitive advantages.

FIGURE 2 (developed during a joint industry project in Norway in late 1990s), illustrates a balanced score card relevant to maintenance. For example Technical integrity is a key factor for the maintenance and life cycle process and therefore technical integrity index provides a good measure for maintenance effectiveness. Indication of a deterioration of technical integrity may justify investment in maintenance in order to improve the safety and economic performance. Processes perspective in this illustration is a measure of quality and effectiveness in the preventive maintenance program as well as quality of the planning and reporting processes.

Correct reporting and staff ownership to the information system is probably the most critical success factor for managing the process of maintenance effectively. Similarly, relationships consist of internal and external relationships addressing existing ways and means of being connected, associated, communicated, and partnered, between different parties engaged in the execution of maintenance tasks. Emphasis could be placed on vertical and lateral relationships between teams and individuals, lateral relationships

between internal processes and further relationships between the company concerned and third-party contractors.

Return on investment, health, safety and environment are important outcome measures for the production unit concerned. The integrity of the plant is an outcome measure of process effectiveness, competencies and relationships but is representing a performance driver for return on investment and HSE. Processes, competencies and relationships are performance drivers for the outcome measures, plant integrity, return on investment and HSE. It is reported by researchers that companies using an integrated balanced performance measurement system perform better than those not measuring their performance.

In addition, health, safety and environment and employee satisfaction, are considered to make this MPM system a balanced and holistic from the organizational point of view. The strategic goals need to be broken down to operating tasks and the performances at the operating level are aggregated to tactical and strategic level for decision making. After considering all related issues and challenges, the MPIs can be grouped in to seven criteria below. See also FIGURE 5.

- Asset/process related, e.g. availability, performance speed, quality and down-time, etc.
- Operation and maintenance task related, e.g. planned maintenance task, etc.
- Cost-related, e.g. maintenance cost/unit, production cost/unit, etc.
- Customer satisfaction, e.g. number of complaints and quantity returned, etc.
- Learning and growth, e.g. skills and competency development, etc.
- Health, safety and the environment (HSE), e.g. number of accidents, etc.
- Employee satisfaction, e.g. employee complaints, retention rate etc.

Identifying Leading and Lagging Indicators

In general, indicators are relative; meaning that what is leading for a department can be lagging for another group or department. For example, maintenance cost incurred can be lagging indicator for production facilities or accounts department whereas it will be lead indicator for maintenance managers or corporate managers, see FIGURE 3.

There is also a need to workout an overall total maintenance effectiveness considering all the factors and criteria as discussed above. In general measures for total maintenance effectiveness must be combined with process owners' capability to change processes and adapt to new technology and work practices without major involvement of resources and at right time.

The MPM framework for the engineering assets suggested at FIGURE 5 is balanced, considering different criteria, holistic for the organization and integrated as a link-and-effect structure to achieve maintenance effectiveness to contribute to the overall objective of the organization and its business units. As shown in the figure, the suggested performance indicators are in different criteria and in three hierarchical levels of operation. Organizations can modify the framework to include their operation specific criteria using the same number or more hierarchical levels.

The challenges associated with the development and implementation of MPM need to be considered along with total

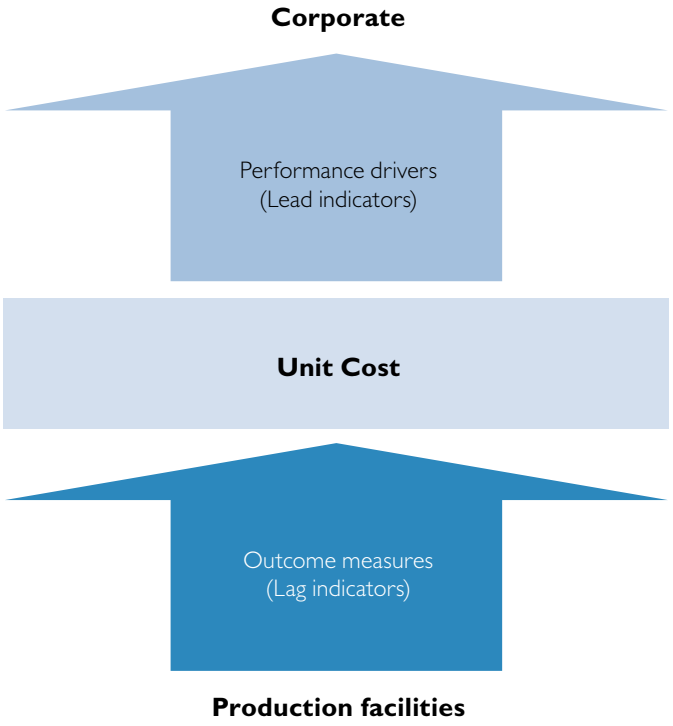

FIGURE 3. *Lag and lead indicators.*

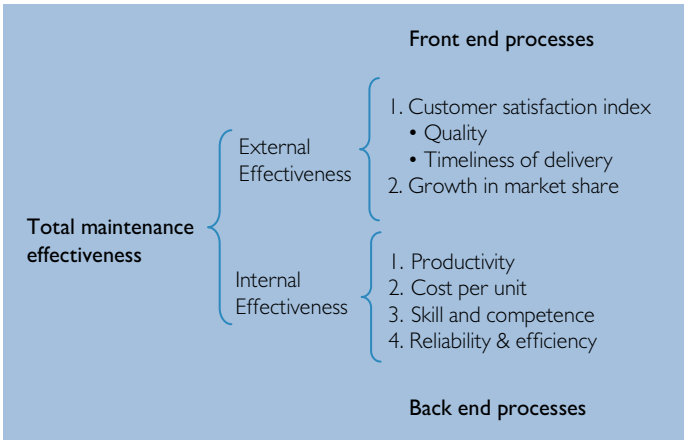

FIGURE 4. *Total maintenance effectiveness based on organizational effectiveness model. Total maintenance effectiveness = Internal effectiveness x External effectiveness.*

maintenance effectiveness. Some of the basic questions require deliberation and critical examination while designing the MPM system. The questions that form the basic challenges associated with the MPM system are:

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 down 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.

TRANSPARENCY OF COMMUNICATION – EVERY PERSONNEL SPEAKING THE SAME LANGUAGE

The SMART test is frequently used to provide a quick reference to determine the quality of

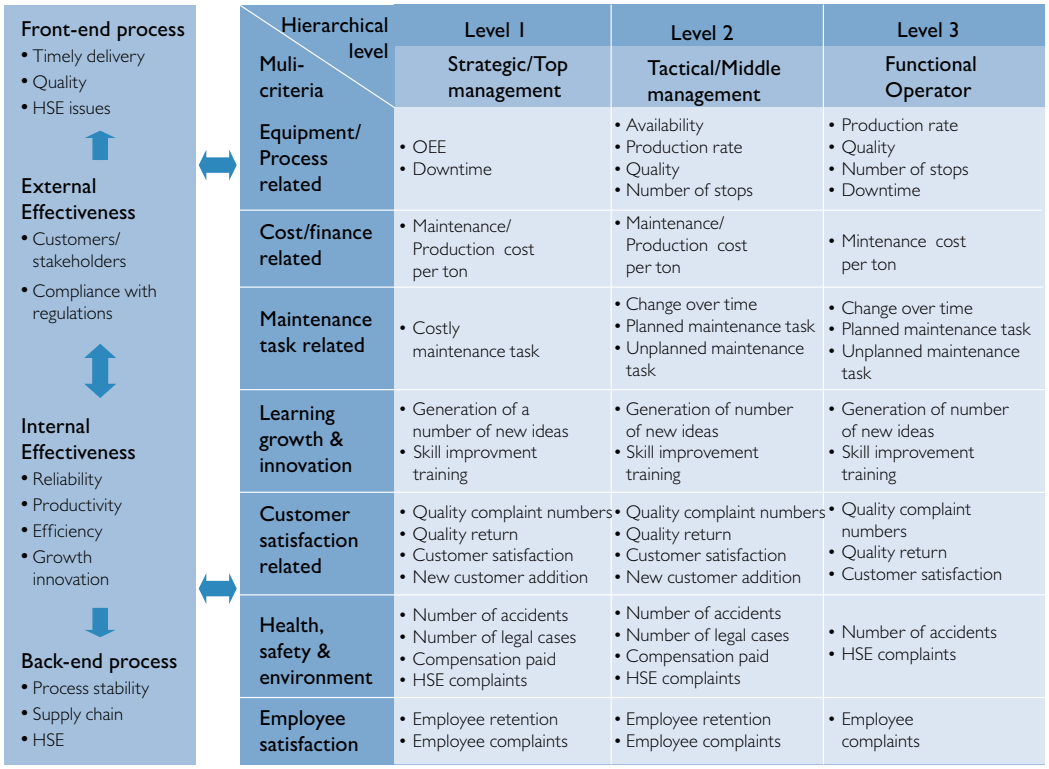

FIGURE 5. *A multi-criteria hierarchical maintenance performance measurement (MPM) model.*

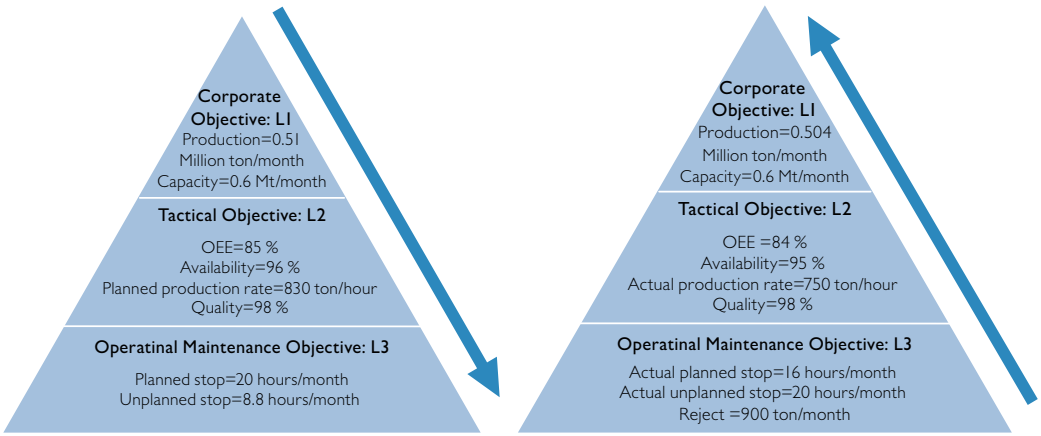

FIGURE 6.
Cascading down of indicator from corporate goals to operational level.

Aggregation of indicator from operational level to corporate level.

the performance metrics (DOE-HDBK-1148-2002).

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 of ore.

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 given time frame.

Application

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 though out the entire organization. Figure 6 illustrates an example of linking corporate goals to operational maintenance objective at shop floor level. It also shows the aggregation from outcome results into indicators and key performance indicators linking them to corporate goals and objectives at the top level of a mining company.

IMPLEMENTATION OF THE MPM SYSTEM

Implementation of the developed MPM system for an organization is very critical. It is reported that fear, politics and subversion, are 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. Lack of communication and dissemination of results are other important issues.

Concluding remarks

Performance measurement of maintenance process is a complex issue as it involves various inputs, outputs and stakeholders. More often than not measuring the contribution and performance of maintenance will always be complex issue especially when intangibles such as quality of service, repair and maintenance are involved. The most important step in developing maintenance performance metrics is to involve the maintenance crew who are responsible for the work to be measured because they are the most knowledgeable people about the work. ■