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**Research Article**

# Critical Study of the Different Types of Maintenance Used in Industry

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**Abstract:** The aim of this study is to discuss and clarify the important features and characteristics of effective approaches in order to perform maintenance management. For this purpose, the relevant literature is examined, classified and analyzed to carry out a comparative study between many methods of the maintenance used in the industry. Deficient maintenance management can severely affect competitiveness of an organization by reducing throughput, increasing inventory and leading to poor performance, Maintenance management of industrial equipment is an important but still relatively neglected by business function In order to achieve world-class performance, more and more companies are replacing their reactive, strategies for maintenance with proactive strategies like preventive and predictive maintenance and progressive strategies like total productive maintenance. While these new maintenance strategies require increased commitments to training, resources and integration. They also tend to improve performance. This article discusses a research project to identify the strong points, weak points between the techniques of maintenance and the relationship between the approaches of maintenance and production methods. A survey was conducted to determine the relationship between the two approaches.

**Keywords:** Advantage and disadvantage, maintenance management, maintenance strategy, manufacturing, performance, production

## INTRODUCTION

Maintenance is the set of all activities meant to keep a system into a condition where it can perform its function. Quite often these systems are production systems. Some maintenance work can be done during production and some can be done during regular production or stops in evenings, weekends and on holidays. However, in many cases, production units need to be shut down for maintenance. This may lead to management problems between the production and maintenance department of a company. On one hand, the production department needs maintenance for the long-term well-being of its equipment; on the other hand, it needs to shut be down in periods where they could well be used for production.

Maintenance productivity is one of the most important issues which manage the economy of production activities. However, productivity is often relegated to second rank and ignored or neglected by those who influence production processes (Singh *et al*., 2000). Productivity in a limited sense has been measured for several years (Andersen and Fagerhaug, 2007). Since maintenance activities are multidisciplinary in nature with a large number of inputs and outputs, the performance of maintenance productivity needs to be measured and considered holistically by using an integrated approach. With increasing awareness that maintenance makes a difference in to the business process; organizations are treating maintenance as an integral part of their business (Liyanage and Kumar, 2003). For many asset-intensive industries, the maintenance costs are a significant portion of the operational cost. Maintenance expenditure accounts for 20-50% of the production cost for the mining industry depending on the level of mechanization. Therefore, the importance of maintenance productivity is understood more and more by the management of the companies.

The organizational role of the company requires a total change n the maintenance techniques, maintenance related costs have been on the increase in recent years (Parida and Kumar, 2006). In manufacturing organizations, maintenance related costs are estimated to twenty five percent of overall operating cost (Cross, 1988), (Komonen, 2002). In some industries, such as petrochemical, electrical power and mining, maintenance related costs may surpass operational cost (Raouf *et al*., 1993; De Groote, 1995; Eti*et al*., 2005; Parida and Kumar, 2006). As such, close attention

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should be paid to maintenance performance measures, measurement and management, in order to utilize the scarce maintenance resources more effectively and in the process, improve organizational efficiency and effectiveness.

According to the CEN-European Committee for Standardization (2001), one of the main responsibilities of the maintenance manager is to chart a systematic maintenance strategy, which takes the three main criteria below into account:

- To ensure the availability of the item for the required function, often at optimum costs
- To consider the safety requirements associated with the item for both maintenance and personal user and, where necessary, any impact on the environment
- To uphold the durability of the item and/or the quality of the product or service provided considering, financial deficiencies

To achieve the overall maintenance objectives, the following strategic approaches are recommended, as either stand-alone and/or jointly (CEN-European Committee for Standardization, 2001):

- Preventive maintenance approach
- Scheduled maintenance
- Predetermined maintenance
- Condition based maintenance
- Predictive maintenance
- Corrective maintenance approach
- Immediate maintenance
- Deferred maintenance

## MATERIALS AND METHODS

For the purposes of this research, a comprehensive and systematic search of the literature related to maintenance, management and maintenance performance measure was conducted. This literature review was performed using, electronic databases Moreover, another research was conducted to include other books and other research medias. In general, several articles were reviewed.

**The development of maintenance:** Maintenance is defined as: "Combination of all technical, administrative and management actions during the life cycle of an item intended to be conserved or restored in a condition where it can perform a required function" PrEN 13306(1998). The industry did not have a high mechanical level before the Second World War, that is, most of the equipment was over-designed and simple. The consequences of failure did not have a strong influence and the effect was neglected (Alsyouf, 2007). Due to this, the industrial equipment was working until failure occurred and when, it was either replaced or repaired. Thus the mentality was: "fix it when it breaks". In the first approach of maintenance no actions were taken to detect the start of failure not to prevent failure but to inf out the effects of the production equipment, this approach can be described as reactive maintenance (Alsyouf, 2007).

The Second World War turned things upside down and everything changed dramatically during the war. This is due to shortage of manufacturing labor hand and an increasing demand on production (Kister and Hawkins, 2006). As a result, the mechanization increased and the manufacturing facilities changed to be more complex (Alsyouf, 2007). To meet the growing demand for war materials, customer goods and to compensate for the labor hand shortages, the technology within manufacturing sector had to develop more mechanization (Kister and Hawkins, 2006). Cost, longevity and availability were now regarded as important factors to achieve the business objectives and therefore, maintenance was considered as a technical manner and became a task of the maintenance department (Alsyouf, 2007). The equipment reliability was now important and production downtime became everybody's concern. The newfound stature of maintenance allowed the maintenance organization to develop and implement periodic, planned and preventive programs (Kister and Hawkins, 2006).

Traditionally, maintenance, with its multifaceted activities, resources, measurement and management, has been important to manufacturing organizations. However, in recent years, the need to manage the different facets of maintenance more effectively has gained added importance, due to changing operational technologies and the changing organizational role of maintenance. In today's open system manufacturing organization, maintenance has a larger perspective. In such organizations, the scope of maintenance has shifted from a narrowly defined operational perspective, to an organizational strategic perspective. Some authors attribute this shift to the utilization of more advanced technologies (Swanson, 1997), increased emphasis on safety and new environmental legislations (Cooke, 2003). In such operational environment, the role of the maintenance manager is critical. As such, maintenance managers are being called upon to integrate and direct the maintenance efforts to meet organizational strategic goals efficiently and effectively (Alsyouf, 2007; Al-Najjar, 2007). Thus, the need for these managers to receive appropriate formal educational training, which incorporate the different facets of their increasing organizational roles, is becoming more important than ever before (Shrivastav, 2005).

**The role of maintenance organization:** Many maintenance organizations are proud of how fast they can react to production troubles or catastrophic failure

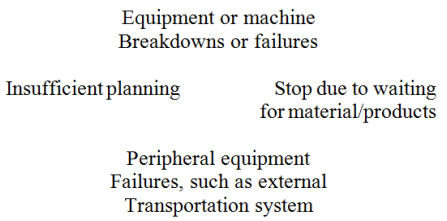


Fig. 1: Examples of production disturbances (Bellgran and Säfsten, 2010)

instead of their ability to prevent such events. Most organization, continue to operate in this way while few admit their commitment adherence to this mentality. The role of the maintenance organization as opposed to the popular belief is to maintain the equipment of the plant i.e. to be proactive and not to repair it after failure i.e., reactive. However, all catastrophic failures cannot be avoided and maintenance must therefore continue to react quickly to unexpected failures (Mobley, 2004). Optimum reliability is one part which determines the production capacity of the plant. Maintenance organization primary function is to ensure that all equipment and systems always are in good operating condition and on line, in other words to reduce such problem (Mobley, 2004).

**Production disturbances:** Production disturbances are a concept which is differently defined depending on which perspective the disturbances are regarded:

- Maintenance perspective
- Production
- Security perspective
- Quality

The prerequisite of finding the best way to handle disturbances, is taking into consideration all these perspectives. Among other things, disturbances can be regarded as a losses (Bellgran and Säfsten, 2010).

Production disturbances can be defined as a discrete or decreasing, unplanned or planned change or disruption during production time, which might affect operational performance, product quality, availability, work conditions, environment, safety etc. (Bellgran and Säfsten, 2010). Thus, the disturbances occurring should be distinguished from desirable, planned conditions. Some examples of production disturbances are shown in Fig. 1.

**Maintenance improvement:** Maintenance organizations are often so enough maintaining equipment and planning eliminate the need at its source are forgotten. Efforts in reliability engineering should emphasize elimination of failures that require maintenance which is an opportunity to pre-act instead of react. The first and most valuable figure to eliminate or reduce the need for maintenance is maintenance improvement efforts (Mobley, 2002). In order to work in a systematic and structured way with improvements it is important to define what a production disturbance is. Naturally, it is difficult to control and improve what is not measured and followed-up. It is required to cooperate when working with improvements and it is then important to have a common view of the production disturbances (Bellgran and Säfsten, 2010).

**Different types of maintenance:** According to Mobley (2004) are there two types of maintenance management that are typically utilized by industrial and process plants; corrective maintenance and preventive maintenance.

**Corrective maintenance:** Definition of corrective maintenance according to the standard PrEN13306 (1998): "Maintenance carried out after fault recognition and intended to put an item into a state in which it can perform a required function."

This management type is simple and straightforward, "fix it when it breaks" (Mobley, 2004), i.e., the things are fixed either after failure or during failure (Moubray, 1997). This maintenance type concerns emergencies casas, repair, unscheduled and remedial tasks (Mobley, 2004). This method has been a major part of the maintenance operations since the first manufacturing plant was built and it sounds reasonable on the surface. But it is actually a no-maintenance approach of management. It is also the most expensive one due to high machine downtime, low production availability, high overtime labor costs and high spare parts inventory cost (Mobley, 2004). The corrective technique does not take any maintenance action until equipment failure. This maintenance management philosophy is rarely used altogether without any preventive tasks (i.e., lubrication and adjustments). Still, in a corrective environment, the equipment are not rebuilt nor repaired to a greater extent until it fails to operate (Mobley, 2004).

**Preventive maintenance:** The preventive tasks mean replacing components or overhauling items at fixed intervals (Moubray, 1997) that is, to premature equipment damage and prevent unscheduled downtime that would result in repair or corrective activities. This approach to maintenance management is predominantly recurring or time-driven tasks performed to maintain acceptable levels of availability and reliability (Mobley, 2002).

The definition of preventive maintenance from the European standard (PrEN 13306, 1998) is presented as: "Maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item.

Preventive maintenance can, according to the standard PrEN 13306 (1998) be divided into three divisions:

**Scheduled maintenance:** Preventive maintenance carried out in accordance with an established time schedule or established number of units of use.

**Predetermined maintenance:** Preventive maintenance carried out without previously condition investigations and in accordance with established intervals of time or number of units of use.

**Condition based maintenance:** Preventive maintenance consisting of performance and parameter monitoring and the subsequent actions. The performance and parameter monitoring may be scheduled, on request or continuously.

**Predictive maintenance and operator maintenance:** There are two additional types of maintenance types which are important to emphasize; Operator maintenance and Predictive maintenance.

**Operator maintenance:** Is defined as (PrEN 13306, 1998): "Maintenance carried out by qualified user or operator."

**Predictive maintenance:** Is defined as (PrEN 13306, 1998): "Condition based maintenance carried out following a forecast derived from the analysis and evaluation of significant parameters of the degradation of the item."

**Proactive maintenance:** Moubray (1997) defines proactive tasks as: "The tasks undertaken before a failure occurs, in order to prevent the item from getting into a failed state. These tasks embrace what is traditionally known as 'predictive' and 'preventive' maintenance." This is in contrary to corrective tasks which deal with the already failed state. Proactive maintenance is based on theoretical risk analyses. Proper countermeasures are taken to avoid failures (WCM overview).The characteristics of proactive maintenance a control over the maintenance resources. With the advent of correct maintenance scheduling and planning procedures, the understanding of what is required of the maintenance resources consist of weekly often change vast and rapid. The weekly planning period can often later extend to monthly planning periods (Smith and Hawkins, 2004).

## COMPARISON BETWEEN PREVENTIVE AND CORRECTIVE MAINTENANCE

When it comes to choosing the method of maintenance you need to perform, it is difficult to choose between corrective and preventive maintenance. There are many different factors that come into play. Here we discuss the advantages and disadvantages of maintenance and preventive corrective.

**Corrective maintenance:**
**Advantages:**

- Lower start-up cost
- Limited personnel requirement
- Potentially increased margins

**Disadvantages:**

- Unpredictability
- Equipment not maximized
- Indirect costs

**Preventive maintenance:** Preventive maintenance can be defined as follows: Actions performed on a time- or machine-run-based schedule that detect, preclude, or mitigate degradation of a component or system with the aim of sustaining or extending its useful life through controlling degradation to an acceptable level.

**Advantages:**

- Reduces break down and thereby down time
- repair and reduces over time of crews
- Greater safety of workers
- Lower maintenance and repair costs
- Less stand-by equipment's and spare parts
- Better product quality and fewer reworks and scraps
- Increases plan life
- Increases chances to get production incentive bonus

**Disadvantages:**

- Catastrophe failure still a Low risk
- Performance of maintenance based on schedule not required
- Risk of damage when conducting unneeded maintenance
- Saving not readily visible without a base line

If preventive maintenance is not the optimum maintenance program, it does have several advantages over that of a purely reactive program. By performing the preventive maintenance as the equipment concept envisioned, we will extend the life of the equipment closer the concept. This translates into dollar savings. Preventive maintenance (lubrication, filter change, etc. While we will not prevent equipment catastrophic failures, we will decrease the number of failures. Minimizing failures lead to maintenance and capital cost savings.

**Predictive maintenance:** Predictive maintenance can be defined as follows: Measurements that detect the onset of system degradation (lower functional state), thereby allowing causal stressors to be eliminated or controlled prior to any significant deterioration in the component physical state. Results indicate current and future functional capability.

**Advantages:**

- Increased component operational life/availability.
- Allows for preemptive corrective actions.
- Decrease in equipment or process downtime.
- Decrease in costs for parts and labor.
- Better product quality.
- Improved worker and environmental safety.
- Improved worker morale.
- Energy savings.
- Estimated 8% to 12% cost savings over preventive maintenance program.

**Disadvantages:**

- Increased investment in diagnostic equipment.
- Increased investment in staff training.
- Savings potential not readily seen by management

The advantages of predictive maintenance are many. A well-orchestrated predictive maintenance program will all but eliminate catastrophic equipment failures. We will be able to schedule maintenance activities to minimize or delete overtime cost. We will be able to minimize inventory and order parts, as required, well ahead of time to support the downstream maintenance needs. We can optimize the operation of the equipment, saving energy cost and increasing plant reliability. Past studies have estimated that a properly functioning predictive maintenance program can provide a savings of 8% to 12% over a program utilizing preventive maintenance alone. Depending on a facility's reliance on reactive maintenance and material condition, it could easily recognize savings opportunities exceeding 30% to 40%. In fact, independent surveys indicate the following industrial average savings resultant from initiation of a functional predictive maintenance program:

- Return on investment: 10 times
- Reduction in maintenance costs: 25% to 30%
- Elimination of breakdowns: 70% to 75%
- Reduction in downtime: 35% to 45%
- Increase in production: 20% to 25%.

**Reliability centered maintenance:** Basically, RCM methodology deals with some key issues not dealt with by other maintenance programs. It recognizes that all equipment in a facility is not of equal importance to either the process or facility safety. It recognizes that equipment design and operation differs and that different equipment will have a higher probability to undergo failures from different degradation mechanisms than others. It also approaches the structuring of a maintenance program recognizing that a facility does not have unlimited financial and personnel resources and that the use of both need to be prioritized and optimized. In a nutshell, RCM is a systematic approach to evaluate a facility's equipment and resources to best meet the two and result in a high degree offacility, reliability and cost-effectiveness.

RCM is highly reliant on predictive maintenance but also recognizes that maintenance activities on the equipment are quite expensive and important for the reliability approaches. The following maintenance program breakdowns of continually top-performing facilities would echo the RCM approach to utilize all available maintenance approaches with the predominant methodology being predictive

**Advantages:**

- Can be the most efficient maintenance program.
- Lower costs by eliminating unnecessary maintenance or overhauls.
- Minimize frequency of overhauls.
- Reduce probability of sudden equipment failures.
- Able to focus maintenance activities on critical components.
- Increase component reliability.
- Incorporate root cause analysis.

**Disadvantages:**

- Can have significant startup cost, training, equipment, etc.
- Savings potential not readily seen by management.

Because of RCM is so heavily weighed in utilization of predictive maintenance technologies, its program advantages and disadvantages mirror those of predictive maintenance. In addition to these advantages, RCM will allow a facility to more closely match resources to need while improving reliability and decreasing cost.

## COMPARING MAINTENANCE MANAGEMENT WITH OTHER MANAGEMENT AREAS

Maintenance has sometimes been described as the last frontier of scientific management. Lately it has drawn scientific attention and has been given greater importance. The area is dominated by technically oriented people whose prime knowledge lies in solving technical and in managing people, but who are not familiar with reliability theory or research operation. Two aspects are typical for maintenance management. First of all, maintenance faces an inherently deterioration and failure process. The state of affairs in a maintenance organization is often dominated by unplanned events. Failures of important equipment may delay long-planned activities. Major decisions, choosing between replacement and repair, may have to be taken quickly. Management, being under constant time pressure, therefore lacks time to become familiar with abstract management science techniques. Secondly, maintenance consists of a multitude of different activities. At an individual activity level it is often difficult to evaluate benefits of maintenance. Hence, at a macro level, it is very difficult to balance

the maintenance budget with its contribution to company profits. Therefore, maintenance is often seen only as a cost function, with all associated negative implications.

**The necessity for maintenance:** Effective and efficient utilization of installed production facilities is a contributing factor to the promotion of industrial growth. One of the prerequisites to ensure the availability of installed production facilities for efficient use is to have an effective maintenance engineering system. With the advent of mechanization and automation coupled with the high cost of capital investment, this prerequisite needs more attention than in the past As a result of increasing the degree of mechanization and automation less people are involved in the direct production work.

Other factors which emphasis the need for effective maintenance systems are:

- Increased production levels
- Rigid production schedules
- Increased machine utilization
- Market competition

Lack of an effective maintenance system in a manufacturing enterprise gives rise to several undesirable consequences some of which are:

- Excessive machine breakdowns
- Frequent emergency maintenance work
- Shortened life-span of the facility
- Poor utilization of maintenance staff
- Lower quality of products
- Delivery dates are not met
- Panic operating changes
- Disproportionate investment in spare parts and maintenance materials,
- Excessive overtime costs

All these contribute to high costs of production and loss of profits.

**Goals and objectives of maintenance:** The aim is not only to achieve increased plant availability through better maintenance management, but also to do so at a low cost relative to the increased profit. Another aim is to maximize plant and equipment effectiveness in order to achieve targeted rates of return on investment. This attests to the fact that organizations and equipment become more sophisticated, maintenance expectations begin to evolve. The principal objectives of maintenance can be stated as follows:

- To extend the useful life span of an item
- To increase availability of installed equipment
- To ensure operational readiness of all equipment required particularly for emergency purposes
- To ensure the safety of people (personnel) using such equipment
- To avoid exorbitant expenses on repair of equipment which might occur if the same equipment was not maintained and is allowed to fail

**Maintenance strategies:** here are several maintenance strategies for use in various fields and manufacturing industries across the world; each developed to suit a particular need but there are in general two types of maintenance which can be classified under two broad categories.

**Factors influencing maintenance strategic developments:** The search to develop a maintenance strategy for critical equipment comes from a deep thirst for maintenance improvement. A good and worthwhile approach to maintenance improvement comes from the successful use and mastery of the key functions of these factors which entails:

- Management
- Inspection
- Planning
- Scheduling
- Execution
- Improvement

These six key functions will form the foundation and backbone of any worthy maintenance strategy to be developed that will be universal and generally be accepted for use in any manufacturing outfit. It's worth noting that each of these entities relates to another and the management functions comes as the common feature to any of these keys. All along the path of the maintenance strategy development methodology, cost factor is vital

## METHODOLOGY

Development of an effective maintenance strategy for critical equipment requires a sound knowledge of the root causes of failure, its possible sources, modes of occurrence and all related variables, as stated in the preceding sections. With this knowledge base, the methodology for the development of a maintenance strategy for critical equipment will be adjudged based on the following modules shown in the Fig.2.

## CONCLUSION AND FUTURE PROSPECTS

This study summarizes the process and framework for managing maintenance based primarily on maintenance methodsand their strengths and

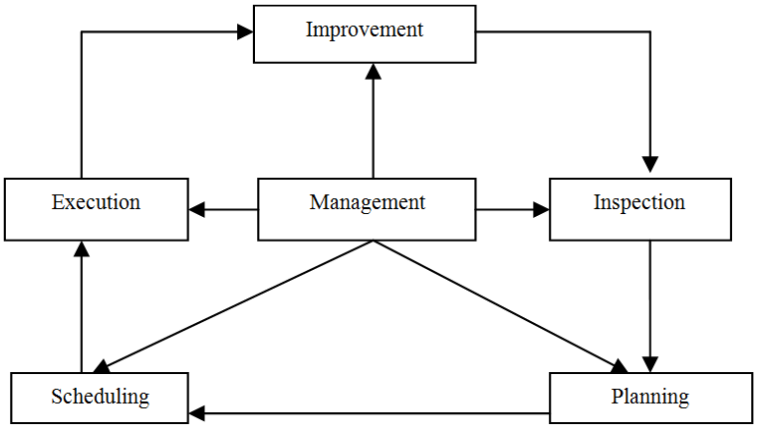


Fig. 2: Steps to successful maintenancestrategy

weaknesses. We propose in the next works maintenance optimization models to develop a simple and cost-effective approach to formulating and implementing maintenance strategies for the manufacturing industry.

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