

## Development Of An Effective Industrial Maintenance Practice For Plant Optimum Performance

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### ABSTRACT

Plant optimization is a sound fiscal decision and this is a key attribute of good operational management. The decision to adhere strictly to the maintenance measurements, controls and efficiencies necessary for optimum performance not only enhances the plant operations, it quite often produces a safer operating facility and protects plant asset or investment. Plant operations rely on dependable acquired knowledge, skills, equipment and maintenance programs for an assured performance while strategies are required to be in place for equipment optimum availability to ensure system operational integrity in order to reduce costs which affect production. This optimized system would ideally give meaning to effective maintenance practice of plant equipment and accepted best maintenance management system. This paper presents a comprehensive review of characteristics of plant equipment and maintenance strategies and proposes sustainable maintenance management performance criteria. Thereby improving business, safety, equipment efficiency and sustain the environment. The goal is to achieve optimum availability and optimum operating condition of the equipment life cycle in a cost optimized approach.

**Keywords:** Development, Maintenance, Optimization, Performance

### I. INTRODUCTION

Maintenance has become a major contributor towards achieving the strategic objectives of an organization [1]. Maintenance management is considered as one of the main pillars for improving the overall performance of production and manufacturing organizations [2]. Maintenance involves planned and unplanned actions carried out to retain a system or restore it to acceptable operating condition [3]. The main objective is to ensure the highest level of availability and efficiency of plant, equipment and buildings in a manner required by production at an economic cost (service cost and downtime cost) [4]. Maintenance operation provides a key role to production activities since total production cost may be greatly reduced as compared to ad hoc decision or strategy [5]. Maintenance operations which some organizations perform only as a corrective function and executed in emergency conditions is no longer acceptable because of the increase in product quality, equipment reliability and personnel safety [5&6].

### II. PLANT OPTIMIZATION

#### 2.1 Synopsis

Plant optimization is when one maximizes plant yield and efficiency [7]. Maximizing plant efficiency is a matter of understanding the characteristics that come to play and implementing those procedures that make the best use of them [8]. This involves evaluating the processes in place and

taking the necessary steps to insure that the plant has the equipment that is best suitable in performing the specified duties and that the equipment is being utilized in the most efficient manner [7, 8 & 9]. It is a necessary ongoing process which makes the difference in operating the facility at peak profitability [10]. It is an endeavor that should be done by qualified professionals who are dedicated to the core of their duties and involved in the daily operations of the plant to achieve process optimization [11].

Process optimization is the discipline of adjusting a variable so as to optimize some specified set of parameters without violating some constraint. The most common goals are minimizing cost and maximizing throughput and equipment efficiency [12]. This is one of the major quantitative tools in industrial decision making [13]. When optimizing a process, the goal is to maximize one or more of the process specifications, while keeping others within their constraints [14]. This can be done by discovering the critical activities and bottlenecks and acting only on them and further strategizes for other part of the system to maintain integrity [15]. Fundamentally, there are three parameters that can be adjusted to effect optimal performance of plant namely;

1. Equipment optimization: The first step is to verify that the existing equipment is being used to its fullest advantage by examining operating data to identify equipment bottlenecks and effect maintenance strategies [16].

2. Operating procedures: Operating procedures may vary widely from person-to-person or from shift-to-shift. Automation of the plant can help significantly. But automation will be of no help if the operators take control and run the plant in manual state [16].
3. Control optimization: In a typical manufacturing and production plants, such as a chemical plant or oil refinery, there are hundreds or even thousands of control loops. Each control loop is responsible for controlling one part of the process and further cascaded, such as maintaining a temperature, level, or flow. If the control loop is not properly designed and tuned, the process runs below its optimum expectation thus process will be more expensive to operate, and equipment will wear out prematurely and affect control loop performance optimally [16].

The process of continuously monitoring and optimizing the entire plant is called performance supervision [16 & 17]. Modern industrial maintenance practices play a very important role in Equipment optimization which mitigates operation interruptions [18]. This requires effective management of maintenance operations, optimization of equipment, equipment reliability and availability. It also involves effective monitoring and maintenance strategies, planning methods, analysis of effectiveness of individual equipment and overall plant efficiency [19], hence this paper concentration is to review equipment optimization.

## 2. 2. Attributes of Equipment Optimization

### A. Optimum Availability

The operations capacity of a plant is determined by the availability of production machinery and their auxiliary equipment. The primary function of the Maintenance Management is to ensure that all machinery, equipment, and systems within the plant are always on line and in good operating condition [20].

### B. Optimum Operating Condition

Availability of critical operations machinery is not enough to ensure acceptable plant performance levels [21]. Maintenance Management has the responsibility to maintain all direct and indirect systems such as skill personnel, spare parts, access to production units, safety assurance and availability of production materials so that there will be continuously functioning of equipment and entire system. Minor problems, no matter how slight, can result in poor product quality, reduce production speeds, or affect other factors that limit overall plant performance [22].

### C. Ability to React Quickly

Not all catastrophic failures can be avoided. Therefore the Maintenance Management must have the ability to react quickly to the unexpected failures should the need arise. This restores the integrity of the plant operation [23].

## III. MAINTENANCE MANAGEMENT AND POLICY EVALUATION

Maintenance is an act of restoring equipment or system into its functioning state or operational mode. Maintenance management is the management system responsible for the organizational and managerial tasks linked to establishing objectives, strategies and implementation of maintenance activities through action plans to monitor and control maintenance programs [24]. The implementation of maintenance objectives and strategies are important to carry out in conjunction with the other functions of the company (e.g. production, safety and procurement/stores). The objectives give meaning to what the company strives to achieve, while strategies give guidelines of how to utilize company resources in order to achieve the company's objectives outlined in the business case. Both present guidelines and references for the dependable work constitute the basis for prioritizing maintenance actions and initiatives [25].

### 3.1 Impact of Maintenance

A well organized and implemented maintenance program minimizes accidents, reduces unplanned shutdowns, and lengthens the mean time between failures (MTBF) of plant equipment. Benefits of this can be categorized as direct and indirect [26].

#### 3.1.1 Direct Benefits

Direct benefits are derived from reduced cost of repairs, reduced downtime of equipment, improved safety of personnel and property and increase in production output [27].

#### 3.1.2 Indirect Benefits

Indirect benefits can be related to improved morale of employees, better workmanship, increased productivity, and the discovery of deficiencies in the system that were either designed into the original system or caused by later changes made in the system [28].

### 3.2. Maintenance Policy

In every organization maintenance policy is derived from the business case. Maintenance management system is set up base on the dictates of the policy [29]. Maintenance Policy outlines the rules for triggering maintenance actions and therefore is an important tactical level decision.

Several types of maintenance policies can be considered to trigger either precautionary or corrective maintenance interventions [30]. The policy can be developed mainly on failure-based maintenance, time/used-based maintenance, condition-based maintenance, design-out maintenance and opportunity-based maintenance. Maintenance policies can be Run to Failure or Reliability Centered Maintenance type [30]. It is worth noting that the formation of maintenance policy is based not solely on technical considerations rather on techno-economic considerations [31]. The kind of policies adopted for the plant or for specific equipment has great impact on maintenance activities, productivity, and facility safety. From the policy, maintenance programs, tasks and activities are developed. Maintenance work procedures are design from the framework of the policy [32].

### 3.3 Maintenance Program

Maintenance program outlines the maintenance tasks to be carried out according to the management maintenance framework with time allocation. This put into context the format of developing the tasks needed to properly maintain the plant equipment. Maintenance program lead the person(s) developing the required maintenance tasks by ensuring development is done consistently for all equipment [33].

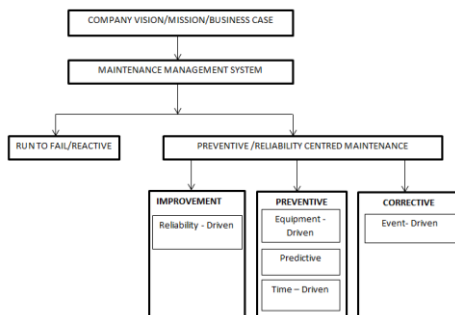


Figure 1. Maintenance Management System Policy Attribute

### 3.4 Relationship between Operations and the Maintenance Department

Although the maintenance department interacts virtually with all departments in an organization, the relationship between operations and maintenance staff is a particularly close one [33]. Operations and maintenance are frequently considered a single function (O&M), and operations personnel frequently perform minor maintenance tasks as part of their regular duties. The two staff groups are strongly dependent on each other, but they differ substantially in their objectives [34]. In general, an operation is defined as a series of actions by operation personnel to make equipment and systems to perform their intended function. This

process includes, for example, operating water pumps, opening valves, and backwashing filters. Operations are usually associated with activities related to the processing and delivery of product or production set-ups, while maintenance department is responsible for keeping the equipment, vehicles, and structures of the company in good condition to actualize its operations [35]. The services provided by maintenance personnel range from involvement in plant construction and installation, commissioning and routine tasks. The performance of maintenance department plays a key role in the success of the company endeavor. In general, the maintenance group provides support services to other departments within the organization as well [36].

### 3.5 Maintenance Plan

A document that outlines the management and technical procedures to be employed to maintain an item usually describing facilities, tools, schedules, and resources [37]. All plants maintenance requires planning and helps maintenance efficiency. Maintenance planning involves identifying parts and tools necessary for the jobs and reserving or even stating them as appropriate [38]. The common characteristics of planning is that after a job requests has been made, a planner determines and advice the necessary parts and tools to be used before the job is assigned [39]. The planner might even write instructions on how to do the job. With this preparatory work done, the craftsperson will be prompted in securing the appropriate tools for the require job. This planning methodology is brought to increase maintenance productivity [40].

### 3.6 Ensuring Maintenance Completion

A formal record is desirable for every maintenance work completed, where the work is of complex detailed, a checklist should be used. The completed checklist should be returned to the maintenance office on completion of the work. Any open maintenance work orders should be kept on report until the supervisor has checked the results for quality assurance and signed off approved. There should be reliability data for records keeping and system tracking [40].

## IV. PLANT ASSET MANAGEMENT AND LIFECYCLE COST ASSESSMENT

Asset management is the systematic and coordinated activities and practices through which a company or an organization optimally and sustainably manages asset and systems, their associated performance namely operations and maintenance, risks and expenditures over their life

cycles for the purpose of achieving the company or organizations strategic plan [41]. Another dimension of asset management is the optimal lifecycle management of physical assets to sustainably achieve the stated business objectives strategically [42]. Lifecycle delivery includes all the activities associated with the execution of an organization’s asset management plan including the creation and acquisition of assets, project management, systems engineering, maintenance, operations, asset rationalization and disposal. It also includes the management of the required access to renew or maintain the assets and the management of the various resources needed to execute the work [43].

#### 4.1 Asset Acquisition Analysis

Asset acquisition has the concept of two parts namely, Primary Asset which comprises of plant equipment and considered as the main integral of the system formation and the Secondary Asset which comes as a supplement to the functioning of the Primary Asset. Critical acquisition areas to consider are specification, procurement, installation and commissioning with reference to operations and lifecycle maintenance cost, illustration in figure 2 [44].

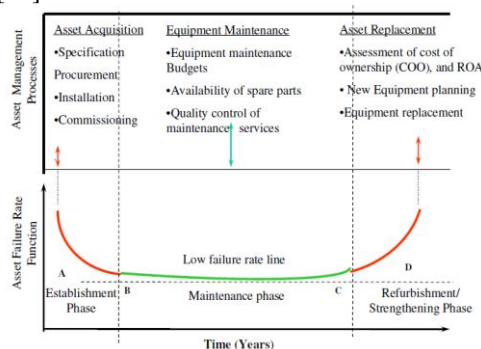


Figure 2

2. Asset Lifecycle Management Process Bathtub Curve; source: [40]

#### 4.2 Equipment Failure Rate and Lifecycle Cost Analysis

Maintenance contribution should be translated into terms of costs. The knowledge of quality costs aids managers to justify investments in quality improvement and assists them in monitoring the effectiveness of the effort made to draw distinction between the cost of the failures and the maintenance cost in relation to time. Therefore proper classification of the different cost of equipment maintenance along their lifecycle cost and failure rates should be understood and considered as the Maintenance Management Resources as illustrated in figure 3 [45].

| (Bathtub) | Equipment Functional Phase   | Management Characteristics   |
|-----------|--|--|
| A-B       | Establishment Phase<br>(High failure rate -due to management and operational problems) | High investment capital outlay<br>Training of maintenance staff<br>Management problems<br>Operational and technical problems<br>Optimization equipment utilization |
| B-C       | Maintenance Phase<br>(Low failure rate)  | Appropriate maintenance budgets<br>Expertise of asset managers and technicians<br>Quality control of equipment   |
| C-D       | Refurbishment / Strengthening Phase<br>(High failure rate - due to aging)              | High maintenance costs<br>Low equipment utilization/productivity<br>Reduced service efficiency   |

Figure 3. Equipment Failure Rate Functions and Strategies: source: [40]

#### 4.3 Maintenance of Equipment and Reliability

Effective planned maintenance management enables an organization to gain uptime capacity to produce and provide goods and services to customers’ satisfaction and consistently [45]. This becomes quite critical in capital intensive organizations because of the heavy investment in capital assets needed [46]. Planned maintenance involves the repair, replacement, and maintenance of equipment in order to avoid unexpected failure during operation. The primary objective of planned maintenance is to minimize total cost of equipment downtime (measured in lost production capacity or reduced product quality). It provides a critical service function without which major business interruptions could take place [46]. Maintenance management programs assume that equipment will degrade within a time frame typical of their particular classification from the bathtub curve concept (Break-in/Commissioning stage, Normal life stage and Equipment worn out stage). With this approach the mode of operation of the system or plant is specific to the variables which directly affect the entire operating lifecycle of machinery and equipment. The mean-time-between-failures (MTBF) of the plant equipment do not remain constant as it deteriorates with age [47]. The normal result of using MTBF statistics to schedule maintenance is to determine catastrophic failure rate which plant warranty is designed to assess. This help to interpret plan and equipment lifecycle cost and analysis as shown in 4.

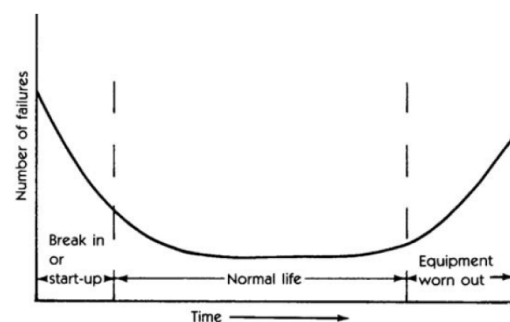


Figure 4. Typical Equipment Bathtub Curve; source: [2]

## V. MAINTENANCE MANAGEMENT SUPPORTS ELEMENTS

### 5.1 Spare Parts Management

Spare parts are one of the main factors in the Maintenance Management, therefore it is very important to appropriately supply the needed spares [48]. If spares are acquired more than necessary it would make the inventory cost, which is a sunk cost incurred. Should there be insufficient supply of spares, it will cause a lack of spare parts for maintenance actions and this will result in cost of lost opportunity to make profit during machine stopped while waiting for spares. Importantly, the appropriated purchase and storage of parts in inventory will be helpful to save costs [50]. Reductions in spares inventory should be a major objective of the maintenance management. However, the reduction should not impair their ability to meet goals [56]. With proper Maintenance Management technology, system can anticipate the need for specific equipment or parts far enough in advances to purchase them on time [52].

#### 5.2.1 Warranty and Insurance

Firms which offer warranties frequently require that certain guidelines be observed in the use of maintenance of the products [50]. A guideline for determining warranty viz maintenance issues should be developed to define if failure should be qualified for maintenance warranty. Warranty usually includes but it is not limited to defects in materials or workmanship and replacement of parts with valid manufacturing failures during warranty coverage [51]. Maintenance Management should ensure processes are in place to effect warranty at the beginning of new production run. In Analyzing non repairable services or products with reference to warranty cost, there is a situation in which the analysis of replacement cost according to different warranty policies has to be considered [52]. In this case consideration should be made on replacement warranty policies already in place. There is also a scenario about software reliability and its warranty cost. In this specific case, it is considered that the life cycle of a software shall include series of activities, namely design, coding, testing, operation and maintenance phases [51]. Nevertheless, within the advantages, it is important to mention that among others features warranty provides legal insurance for damages or default services.

#### 5.2.2 Warranty and Outsourcing

Outsourcing has become a strong complement to the resources of a company that wants business development and expansion [50]. The warranty and subcontracting appears to be linked to the theory of agency [51]. As the definition of outsourcing means when a company

purchases a product or process from an outside supplier rather than producing it in house, in other words outsourcing is like subcontracting and consequently it has advantages and disadvantages. This fact has caused numerous organizations the re-evaluation of procedures when engaging outsourcing activities. The outsourcing of technical tasks does not guarantee successful completion nor ensure that the best interests of the company will be accomplished [52].

In addition to this and regarding the warranty of outsourcing of maintenance activities, it is suggested to compose levels of externalization progressively in time, increasing internal knowledge and control about activities before recruiting a new one that is to carry out as partial outsourcing [53]. Another advantage by using an independent third party warranty servicing company is that the main organization can focus on new and existing projects rather than spending a disproportionate amount of time and effort on warranty works [54]. In any case, in order to implement strategies as a possible externalization, one needs an effective warranty management system that deals with aspects such as data collection, model building and analysis as well as tools for effective decision-making [55].

### 5.3 Post Maintenance Test

Post-maintenance testing (PMT) helps increase the safety and quality of maintenance performed. Basically, PMT has three objectives namely, to ensure the original deficiency has been rectified appropriately, ensure no new deficiencies have been introduced and ensure that the item under consideration is ready to perform its specified function and cause no harm to personnel and other properties around [56]. PMT should be carried out after all types of maintenance activities have been performed as considered appropriate. Testing should commensurate with the specific type of maintenance accomplished, the importance of structure/system, part of the equipment reliability and safety compliance. In some situations, this may only require verification and check list, but in others formal documented PMT may be necessary [57].

### 5.4 Maintenance Quality and Safety Compliance

Quality may be defined as conformance to requirements or degree to which a product, function, or process satisfies the needs of customers and users [46]. Maintenance quality assurance is the action which determine parts, equipment, or material maintained, modified, rebuilt, overhauled, or reclaimed conform to the specified requirements [47]. Maintenance quality is important because it provides a degree of confidence that the concept of project execution and maintained or repaired equipment and systems will operate reliably and

safe [48]. It is essential that maintenance engineering should strive to eliminate hazards or control potential safety threats to ensure satisfactory protection to people and material from electrical shock, high noise levels, fire and radiation sources, toxic gas sources, protruding structural members, and moving mechanical assemblies [49]. Quality maintenance practice and personnel safety are important factors in many systems performance. Good quality maintenance leads to good results reducing or eliminating unexpected failures, lower costs, better safety, and increased confidence in work performed [50]. This can be measured after the specification audit or performance expectations to ensure quality and safety maintenance work is done [51].

## 5.5 Maintenance Record Keeping and Reports Ethics

### 5.5.1 Record Keeping

The success of a planned maintenance program depends on reliability of data [58]. To have an effective Maintenance Management system it is imperative that maintenance works and test inventory data on all equipment should be completed and readily available throughout the service life of the equipment. To that effective, record keeping is very important and all forms and reports should be organized to provide ready accessibility to data when needed and to flag down problem areas [59]. Such data may also be used over the years to analyze trends for equipment deterioration. If data are not recorded and maintained properly, the whole purpose of Maintenance Management will be in disarray [60].

### 5.5.2 Reports and Communication Techniques

Reporting on maintenance work accomplished is essential to any effective Maintenance Management system. Proper report can give the Maintenance Manager significant insight into the successes and problem areas in the maintenance program. Using timely reports, Maintenance Managers can reprioritize, reallocate staff, or use other techniques to keep the maintenance program on track [61]. The success of maintenance activities are highly dependent on how well information flows and the involvement of personnel in communication with others. Examples of successful problem solving shows how information is managed and this promote coordination and team work [62].

## VI. CONCLUSION

In general the focus of achieving plant optimum performance through equipment optimization has been illustrated in all the aspects that pertain to effective maintenance practice. The

areas of plant optimization were dealt with the characteristics which introduced the functioning and attributes of Maintenance Management system of an organization. Plant asset management and life cycle cost assessment proved the essence of equipment maintenance and reliability with the illustrations of the importance and application of reliability bathtub curve and failure rate characteristics.

Warranty and insurance which in engineering practice seems to be foreign to equipment maintenance practice has been considered adequately and the expectation when outsourcing is sorted. Record keeping and reporting or proper communication techniques should be convincing and credible to all forms of maintenance management system. In order to achieve the targeted equipment maintenance performance, efficient maintenance programs at workplace must be developed and given the upmost priority envisaged. Management of quality and safety to personnel and equipment must not be compromised. Efficient data recording system and accurate information processing should be promoted in all Maintenance Management system.

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