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# Implementation of Computerized Maintenance and Management System in Wine Factory in Ethiopia: A Case Study

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## Abstract

The productivity improvement is being main concern of all industries in spite of the type of product and amount of recourses or production system. One of the wine factories (Awash wine factory, Ethiopia) is also struggling to achieve its expected productivity since 1970s because of its poor maintenance management system. So far, productivity has been achieved by implementing various methodologies exclusively computerized maintenance and management system. Accordingly, the main aim of the study is to enhance productivity through smart maintenance management system. The current chapter emphasis on effective maintenance strategy and management system as the solitary way of improving productivity of the case company. The study used descriptive research design by applying both quantitative and qualitative research approach. Maintenance strategy followed by the company (brake down), frequent failure of critical machines, poor maintenance management system, lack of pertinent attention on maintenance, inadequate maintenance budget, considering maintenance as a cost center rather than a business center were the foundations for the problems. Arising from these problems, this study proposed smart maintenance strategy (Preventive Maintenance) and management system tool (CMMS) that improves reliability of machines reduce frequency of equipment failure, reduce breakdown time, decrease cost of maintenance, and then enhance productivity.

**Keywords:** CMMS, maintenance, management, wine factory, preventive maintenance, work flow

## 1. Introduction

The production system maintenance has evolved to be one of the most important areas in the business environment since few decades [1]. The growth of global competition caused remarkable changes in the way of production operation and process. These changes have been affected maintenance management and made its role even more essential in business success. Implementing maintenance management concept is one of the significant changes in production companies [2]. Consequently, maintenance management is a significant part of activities that impacts on production performance.

As automation and mechanization came into picture to change the production processes are converted from manual to machines in high end [3]. Accordingly, the global market is working in one-faced industrialization and to be competitive. Hence, every industry is striving to improve the productivity through different types of tools, techniques, systems, and philosophies. Improved maintenance management system is the best but unseen way that should be used by different manufacturing industries. The role of maintenance management must change to support the growing worldwide competition. It can no longer limit its role to immediate reaction to emergencies and overpower problems with more bodies and excessive overtime. In other words, maintenance should not always be reactive rather it should be proactive. In this regard, there is a need of executing maintenance more effectively.

The industries minimized the losses by locating right systems, infrastructure, process of the product development, and all these executed in a well manner. Hence, the operation will become stable to maximize the production output. This type of improvement is also known as maintenance excellence. It can redefine the roles, responsibilities of traditional, and even maintenance process is also necessary to improve to enhance the asset useful life and cost as well [4]. It can run like any other for-profit business and expected to meet its critical contribution to a fully integrated plant organization. All of these results are significant reductions in maintenance spending. It is not unusual for organizations to experience as much as a 50% reduction in maintenance cost as a result of moving from a reactive style of management to a preventive approach [5]. Therefore, appropriate maintenance resembles the improved management system in industries. Accordingly, preventive maintenance management has been introduced to repair or replacement of components, accomplishment of servicing with information management system. All of them are organized and implemented clearly to exploit the convenience of operational tasks in the industry.

However, productivity should be linked with maintenance management system and then only the possible improvements are occurring effectively. Productivity is associated with the outcomes established from the organization by what extent the inputs are accessing into the system [6]. The link between productivity improvement and maintenance management is well established. Proper maintenance management maximizes the performance and availability of machinery, which leads to increased productivity. Equipment effectiveness is no longer restricted to availability, but involves other factors, such as quality and efficiency. The impact of maintenance management on business performance aspect such as productivity and profitability has increased indefinitely in recent times due to its role in ensuring and improving machine availability, performance efficiency, product quality and swift delivery, environmental and safety requirements [7]. Therefore, one of the main areas for productivity improvement is maintenance management and so the research focuses on how to improve the productivity of Awash Wine Share Company through effective maintenance management system.

Awash Wine Factory is Ethiopia's longest established wine maker and supplier starting from 1936EC. Wine is the end product of the complete/partial alcoholic fermentation of grapes juice in many processes. Different machines and equipment are used in the process of wine production. In the course of time, these processing machines and equipment may fail regularly and resulted in reduction of productivity. Failures decrease production as well as erode profits off. The reduction in productivity can arise either through maintenance cost or increasing in production time. Higher plant-reliability leads to reductions in the frequency of equipment failure and wastages of energy. This study focuses on the investigation of the existing maintenance problems of the case factory and proposed the best solution

that increase the reliability of the machinery and then enhance productivity. Consideration is focused like, maintenance management system to improve the output, machinery condition, operation standards, and reasons for failure, while simultaneously enhance productivity through reducing the downtime of machinery and overall maintenance cost. Hence, possible solutions have been found to resolve the maintenance system and its strategy to minimize the machine downtimes and the cost for maintenance. All these can be controlled with the preventive problems at the beginning by observing the failure root causes and also, proper leadership over the operators, testers, and helpers in the system. Moreover, the chapter tries to find the behavior of the industry to enhance the productivity by implementing smart maintenance strategy and management system, which is suitable to the factory based on its objective.

### **1.1 Maintenance management**

Accorsi et al. [8] stated maintenance management as a business concept that describes the successful and efficient management of maintenance issues involved in the upkeep, operation and productivity of a factory, manufacturing facility or plant.

Maintenance management is considered as the collective actions like administrative, managerial, and technical tools, and over the product is to be produced without failures in the factory. Also, maintenance management helps to change and understands the state of functions or combination of its actions of the product to perform effectively. Accordingly, maintenance management is regulating the objectives which are given to produce a part and makes sure that the described targets are necessary to assign carefully from the department. To fulfill the given objectives, management methods such as strategies and responsibilities are to be planned and controlled by supervising economical aspects in the factory. This is closely aligned to other such notions found in modern maintenance literature. Further definitions consider maintenance management as the management of all assets owned by a company, based on maximizing the return on investment in the asset.

Maintenance management may be described as the function of providing policy guidance for maintenance activities, in addition to exercising technical and management control of maintenance programs [9]. Maintenance management system consists evaluation and analysis of indicative control variables such as performance, quality, equipment history and cost, and systematic implementation of programs like planned preventive maintenance, computerized maintenance management system, reliability improvement, cost reduction, and skill development schemes.

An effective maintenance management might be characterized as the product of prudence. Good maintenance programs and the efficient management systems behind them are essential for economically viable and operationally safe machinery. But most of the factories including awash wine factory lack appropriate machine/equipment maintenance strategy and management system.

A good maintenance management system helps to accomplish minimal downtime [10]. The management of maintenance is equally important with performing maintenance. A good maintenance management system makes equipment and facilities available. If the required equipment or service is down, or if the machine stops short of completing a job, time and money are wasted.

Literature on maintenance management has so far been very limited [11]. Basic steps of maintenance management stated that are request, approval, plan, schedule, performing work, recording data accounting for costs, developing management information, updating equipment history and providing management control reports [10]. Generally, the size of the maintenance group is determined in the



company for achieving superior management and their control. Previously, the size could be varied 5–10% to the operating force. Whereas, now the trend has been changed like the size of the maintenance efforts that are increased significantly when compared with operating force. The increment of the size is because of advanced technologies introducing in all companies. It shows the maintenance requirements are greater than the necessity of manual operators.

The main goal of the maintenance management is to increase productivity and also profits from the effective operations by which many areas are to be considered and focused in the organization. It is very important to maintain the equipment over a prescribed schedule and plan in a company. In addition, practice of preventive maintenance guidelines and warranties enhances the productivity by saving company's budget in maintenance costs and acquired the overall safety of the crews.

Besides, inventory management is also necessary to control the effective business in the organization. It reduces the overhead and physical space on the stock parts and goods for better utilization. Definitely, the company's efficiency is increased professionally by managing the inventory. However, maintenance department acts at where the company is consuming bulk of its overhead costs. Consequently, business philosophy and approaches have been adjusting according to the management costs. Recent trends that have been developed in maintenance technology would convince to enhance the company's margins.

In other side, maintenance system could be seen as input to the output. Here, manpower, equipment, management, etc. are considered as input. Whereas in output, well equipment configuration and working conditions to operate effectively. Similarly, approaches and philosophies are to be maintained when the company needs to enhance its profit margins.

A good maintenance management system makes equipment and facilities available. If the required equipment, machineries or service is down, or if the machine stops short of completing a job, time and money are wasted. A good maintenance management system helps to accomplish minimal downtime [9].

An effective maintenance management encompasses the following:

## **1.2 Maintenance policy**

These are rules or set of rules describing the triggering mechanism for the different maintenance actions. It is a question of what triggers maintenance actions. The common maintenance policies are: failure-based maintenance (FBM), condition-based maintenance (CBM), opportunity-based maintenance (OBM), can be sorted in this category.

## **1.3 Maintenance inventory/material control**

Inventory is stores of goods and stocks kept to meet future demand. In manufacturing industries, items in inventory are called stock keeping items that are held at a stock (storage) point. Usually, the stock keeping items are raw materials, work-in-process, finished products, purchased parts, and supplies.

There are two types of inventories; independent and dependent demand inventories. Independent demand inventories are finished products inventory, while dependent demand inventories are inventories of raw materials and in process goods. The demand for independent items is forecasted, while the demand for dependent items should be calculated from the production requirements for independent demand items [12].

The objective of inventory management system is to make decisions regarding the approved level of inventory and changes in the level of inventory.

Various types of inventory management systems incorporate different decision rules toward inventory. Some are dependent on time and others on the levels of inventory, but the essential decisions are the same.

All inventory systems can be classified as one of the three varieties based on the above basic concept:

- Reorder point system
- Periodic review system
- Material requirement planning system

Steps such as job planning, coordinating with purchasing, coordinating with stores, coordination of issuance of materials, and reviewing the completed job can help reduce material related problems [13].

In the middle of the nights cannot be able to check the spare parts following an urgent call from the operating manager. However, many large companies have been arranged few sort of computers to control the spare parts ordering and warehousing. But, there is no alternative to check spare parts by individual knowledge like what computer can do regularly. Also, the spare parts are necessary to check whenever it is necessary to reduce the time and cost. For this, large companies have special arrangements to major equipment spare parts storage. The boxes have all the spare parts in an arrangement with size and stock numbers to make easy process. It will be consumed wherever the work has been carried out and then it will be returned with all lists of consumed parts to the warehouse.

This is also the time to check on the availability of special tools. These should be kept in a separate box, inventoried at regular intervals, and generally treated as a valuable spare part or essential resource.

#### **1.4 Principles of spare part inventory**

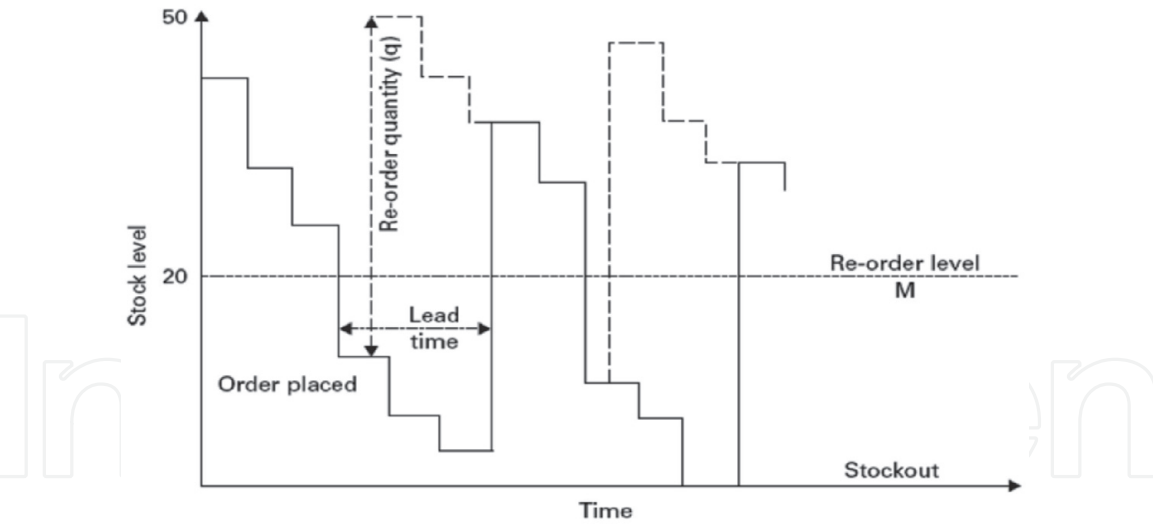
To facilitate the setting of inventory control policies, spare parts can be classified according to their usage rates into fast moving (where the demand is greater than, three items per year) and slow moving (demand less than three times per year).

#### **1.5 Spare part inventory for fast moving parts**

The main aim of the spare part administration activities is to control the holding stock cost against the running out cost. Inventory techniques are used to control the procedures which will reduce the cost of the following stocks such as running stock, replenishing stock, and holding stock. Two basic levels are considered to control the policies for enhancing the spares:

- i. Re-order level: replenishment has been driven by the stock falling to fix the re-order levels;
- ii. Re-order cycle: stocks are reviewed and replenishment has been allowed.

In the re-order level policy, the so-called “two-bin” system (**Figure 1**): the inventory policy is set in terms of a re-order level  $M$  and a re-order quantity  $q$ . Continuous monitor has been done over the stocks, and replenishment order to a fixed size  $q$  is ordered when the stock is on-hand falls to or below a fixed re-order level  $M$ . Hence, re-order levels are used as reservoir which can reduce the



**Figure 1.**  
*Re-order level (source MTB by Alembazewu).*

possibilities of running out of stock caused from the dwell lead time and the random variability of demand. The outcome of the stock holding is as shown in **Figure 1**. Here, solid lines describe the stock held, and the dotted lines reveal about stock on-hand.

The expression for re-order quantity is:

$$q = \sqrt{2DC_o}/C_h \quad (1)$$

where  $q$  = reorder quantity;  $C_o$  = ordering cost;  $D$  = mean demand per unit time;  $C_h$  = holding cost.

Assume stock is re-ordered at regular time interval.

Lead time between order and delivery is negligible.

Negative stock is not allowed by the policy.

Constant rate of demand per unit.

The reordering level  $M$  is calculated as:

$$M = DL + K\sigma\sqrt{L} \quad (2)$$

where  $L$  = lead time,  $\sigma$  = standard deviation of demand per unit time,  $k$  = normal standard variety.

**Maintenance work order system:**

A work order is approved and given the directions in a separate or group vise to carry out the tasks. In this, all maintenance activities and responsibilities are covered to control the costs and to enhance the job performance. Work order should at least contain information such as requested and planned completion dates, work description and its reasons, planned start date, labor and material costs, item or items to be affected, work category, and appropriate approval signatures.

The two main parts of work order system are:

1. The documents required to facilitate work planning, execution and control, and the work order flow process.
2. The basic documents required for the work order system include the work order, materials and tools requisition forms, job card, maintenance schedule, maintenance program, plant inventory, and equipment history files.

Detailed written instructions for any work or activities (job) to be carried out, in any component or part of a plant/equipment/machinery, must be clearly shown in the work order [14].

## **1.6 Equipment records**

Equipment records consist the files including inventory, job performed, and maintenance cost. All these activities are well mannered which can be done while performing the jobs. Also, the maintenance costs are categorized in a historic profile manner. In general, stores and accounting departments provide the information regarding inventory. Operations, drawings, service manuals, warranties and so on are included in the files.

## **1.7 Maintenance job planning**

Job planning is an essential element of the effective maintenance management. A number of tasks may have to be performed prior to commencement of a maintenance job; for example, procurement of parts, tools, and materials, coordination and delivery of parts, tools, and materials, identification of methods and sequencing, and coordination with other departments. Job planning is considered as a main technique to make good observations and preventive maintenance. Here, the primary job is to complete what parts to be maintained and what is the best method to enhance the performance of the jobs. Skills, talent, and good deal time are necessary to accomplish the better procedures. However, this should be performed to gain the good experience to train the future design engineers. But, writing skills are also an important qualification along with practical experience in many practices. The way of writing the language is short, concise, and clear to understand easily. All the statements should be written clearly and the following should be followed strictly:

- Title and identification number must be given for each and every procedure.
- Mention the purpose of the task.
- List out the tools, parts, and reference documents.
- Safety precautions are displayed clearly.
- Location of the job to an operator should be stated effectively.

When the procedure is completed and turned into maintenance control, the planner or scheduler should note any additional work required and see that it gets done according to priority.

## **1.8 Maintenance scheduling**

Maintenance scheduling is as important as job planning. Schedule effectiveness is based on the reliability of the planning function. Fixed interval maintenance tasks and schedules are generally to be considered only when the option has to control the failures detected in advance. Hence, the planning for identifications and preventive levels can be finalized in days, weeks, and even months together soon to make sure that the time for production must be convenient.



## 1.9 Backlog control and priority system

Maintenance management effectiveness is having many determining factors in that one of the most promptly used factors is amount of backlog. These backlogs are important to manage the manpower and workload necessities in the organization. In addition, it uses in making the overtime decisions, assigning the jobs and recruitment, subcontracting, etc.

### 1.10 Performance measurement

Performance measures are necessary and it has been implemented in successful organizations so that measures can be controlled in various manners. Hence, it can be used as powerful tool to measure all the activities before and after the tasks to enhance the productivity of the organizations.

### 1.11 Maintenance strategy

Based on views, maintenance strategy includes: Corrective Maintenance (CM), Preventive Maintenance (PM), and Predictive Maintenance (PRM) [12].

#### 1.11.1 Corrective maintenance

This type of maintenance has been used to recollect the items in satisfactory levels after it has a repair or after degraded below its performance. Planning is also to be considered to maintain the tasks and for logistics which can improve the efficiency of the company. The establishment of the maintenance and logistics requirements is accomplished through analysis of the system's designed-in maintainability and reliability features and attributes, whereas it is most expensive approach to make the maintenance. Service levels should be generally below the levels which can be acceptable. Sometimes, failures happen inappropriate times and hence, interrupt the production system severely. Definitely, maintenances are most expensive because resource planning is not been considered. But, parts need express movement, and the cost is also in effective manner. Overall, the corrective maintenance has been used in successful companies.

#### 1.11.2 Preventive maintenance

It is "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."

PM is maintenance performed to retain a system in a satisfactory operational condition by inspection, and subsequent repair or replacement, and by scheduled overhaul, lubrication, calibration, etc. Poor maintenance practice will actually degrade the condition of the system. Poorly executed preventive maintenance will result in significantly lower operational reliability, higher maintenance cost, and unnecessary downtime.

Preventive maintenance is any planned maintenance activity that is designed to improve equipment life and avoid any unplanned maintenance activity. All these levels are used to control the small failures before they arise in equipment outage. With this PM, many potential issues can be controlled before they occur.

Preventive maintenance is considered majorly in two factors. Such as, cost of the program and the utilization of the equipment.

Also, preventive maintenance can be characterized as follows:

- a. **Scheduled Preventive Maintenance:** it can be carried out on size of use and the time schedule.
- b. **Predetermined Preventive Maintenance/Time Based Maintenance (TBM):** it can be carried out without considerations of previous conditions with an interval times.
- c. **Condition-Based Preventive Maintenance:** it is needed when the equipment is monitored repeatedly. The main aim of the maintenance evaluates and concludes the equipment that is necessity of the repairs and what conditions actions to be performed without suffering a breakdown. Many large and successful companies implemented this type of maintenance through automation techniques like PLCs (Programmable Logic Controllers). Respective signals to find out the failures are produced automatically using automation. However, the initial costs and start-ups are considered as very high when established by automation.

#### 1.11.3 Elements of preventive maintenance

Activities of maintenance function could be either repair or replacement activities, which are necessary for an item to reach its acceptable productivity condition or these activities, should be carried out with a minimum possible cost consists of different activities in a given sequence.

Mentioned below are the most common preventive maintenance activities/elements:

**Inspection:** periodically inspecting materials/items to determine their serviceability by comparing their physical, electrical, mechanical, etc., characteristics (as applicable) to expected standards.

**Servicing:** cleaning, lubricating, charging, preservation, etc. of items/materials periodically to prevent the occurrence of incipient failures.

**Calibration:** periodically determining the value of characteristics of an item by comparison to a standard; it consists of the comparison of two instruments, one of which is certified standard with known accuracy, to detect, and adjust any discrepancy in the accuracy of the material/parameter being compared to the established standard value.

**Testing:** periodically testing or checking out to determine serviceability and detect electrical/mechanical-related degradation.

**Alignment:** making changes to an item's specified variable elements for the purpose of achieving optimum performance.

**Adjustment:** periodically adjusting specified variable elements of material for the purpose of achieving the optimum system performance.

**Installation:** periodic replacement of limited-life items or the items experiencing time cycle or wear degradation, to maintain the specified system.

#### 1.11.4 Predictive maintenance

Another type of maintenance allows the forecasting of failures through analysis of the condition of the equipment. The analysis is generally conducted through some form of trending of a parameter such as vibration, temperature, or flow. Predictive maintenance allows equipment to be repaired at times that does not interfere with production schedules. This removes one of the largest factors from the downtime cost. The equipment service level will be very high under this type of

maintenance. The comparison in different maintenance strategies is shown beneath in **Figure 2** and **Table 1**.

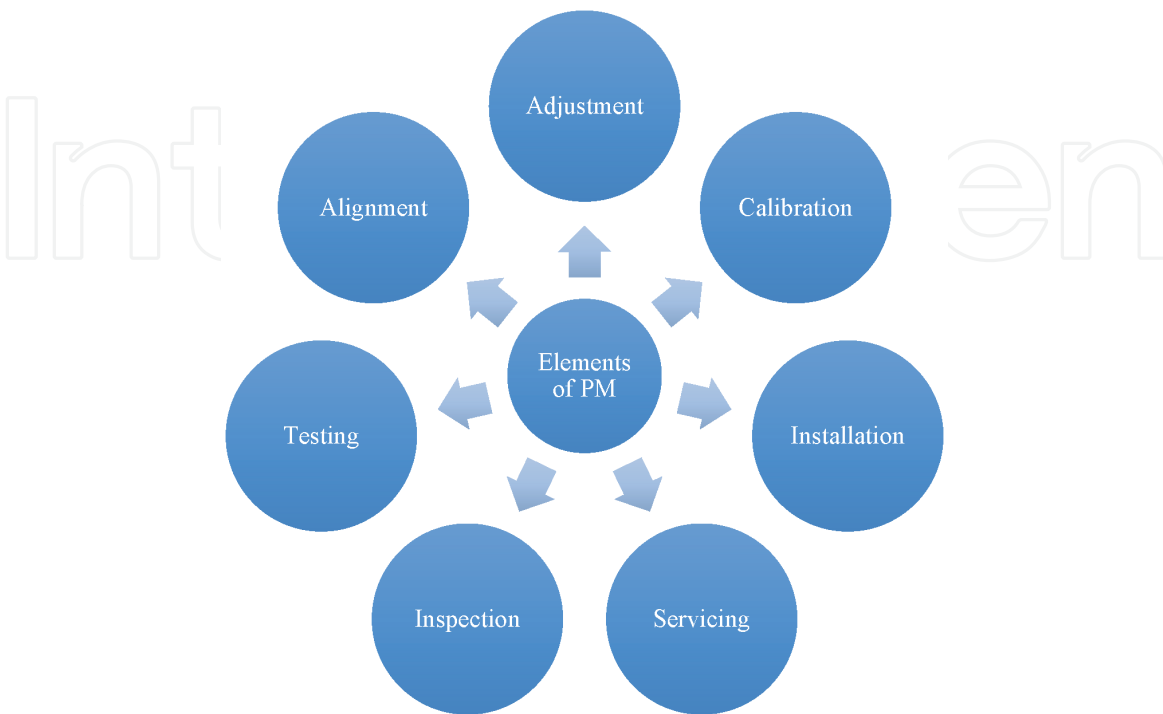
**1.12 Maintenance planning, priority, scheduling, and control system**

The existing system is observed and revealed that the planning of the maintenance and control system was not fully developed and carried out in a proper manner. Hence, proper planning, Scheduling, all necessary activities can be used in the organizations to minimize such kind of challenges/issues.

**i. Maintenance planning**

Planning is defined as the determination of overall all essential elements required to perform a job before its start time in advance. Good observations and preventive maintenance are necessary to find out the volume of size produced using the machines/equipment in daily, weekly, monthly, and yearly. This helps the maintenance to find the free time of the equipment and thus can save the time and cost. The following factors need to be considered in order to make a plan and schedule precise PM.

- Availability of storage information and required parts
- Availability of skilled labors
- Availability of necessary tools
- History of Machine and Equipment
- Working environment or condition
- Manufacturers recommendation



**Figure 2.**  
*The seven elements of preventive maintenance.*

Strategy	Depiction	Payback	Limitation
Preventive maintenance	Schedule of planned maintenance actions aimed at the prevention of breakdowns and failures. Scheduling maintenance activities based on defined time intervals. It is assumed that equipment condition is directly related to time or use.	Prevent failure of equipment before it actually occurs. Preserve and enhance equipment reliability. More accurate and effective equipment maintenance due to application of recent technological advanced inspecting tools. Reduces reactive maintenance and provides a structure to maintenance actions. Flexible, energy savings, cost savings over reactive. Low cost, reduction in failures and breakdowns, extension of equipment life, improved trade-in/resale value of equipment, increased equipment reliability, increased plant productivity, fewer surprises, reduced cycle time, increased service level for the customer, reduction in the number of defective parts, and reduced overall maintenance	Does not totally eliminate unexpected equipment problems. Unneeded maintenance performed regardless of condition. Wastes resources/labor and results in large inventories.
Reactive maintenance	Remedial action carried out due to failure or deficiencies discovered during preventive maintenance, to repair an equipment/item to its operational state. Fix or replace a device, only after failure. Suitable for noncritical and low cost equipment.	Low cost/resources required. Little time, effort or expense for maintenance until absolutely necessary.	Unscheduled maintenance action, potential safety hazards, and increased costs due to unplanned maintenance and associated downtime, overtime, spare parts, and secondary damage.
Predictive maintenance	Assesses the equipment health through diagnostics testing and/or on-line monitoring to find and isolate the source of equipment problems.	Predicts when a device is likely to fail, minimizing the risk of random failure. Directs actions aimed at failure root causes as opposed to faults or machine wear conditions. Increased availability, quality, and safety.	High investment in diagnostic equipment and training. Results in being proactive in areas which have little effect on the plant's operation.

**Table 1.**  
*Comparison with in the three maintenance strategy.*

- Criticality of machines and/or equipment
- Type of training and/or skill manpower to assist maintenance
- The task performed by the machine related to time
- Budget allocation

## ii. Maintenance Priority

When the individual pieces of equipment have been identified for preventive maintenance, there must be a procedure for identifying the order in which they are to be done.

Awash wine factory uses first come first serve (FCFS) principle when it makes the maintenance action but this principle is not appropriate in such companies. The problem with this “first come, first served” method is that the more desirable work in friendly locations tends to get done while other equipment somehow never gets its preventive maintenance.

Need Urgency Customer Rank Equipment Criticality (NUCREC) is the recommended way of work scheduling. The NUCREC priority system helps to ensure that the most important items are done first. Also, it helps to recognize the crucial factors and enhance on the Ranking Index for Maintenance Expenditures (RIME) in many conditions. Ratings are decided based on the priority of the customer rank. This rating has been varied from one organization to another based upon the needs of particular parts produced in the company.

The rating system over the scale has been recommended from number 1–4. Generally, people will follow the numbering as number 1 is first choice to work get it done, similarly the NUCREC system does number 1 first.

**Need urgency ratings include as follows:**

- Rate 1: for emergency like safety hazards with potential further damage if not corrected immediately
- Rate 2: downtime of the equipment which produces less revenue than expected
- Rate 3: preventive maintenance and repetitiveness
- Rate 4: esthetic look and appropriate

**The ranks of the customer are:**

- Rate 1: top management
- Rate 2: production lines through direct revenue associations
- Rate 3: middle management, R&D, and frequent customers
- Rate 4: all others

**The criticality ratings of the equipment are:**

- Rate 1: effect of large areas includes utilities and safety systems
- Rate 2: major equipment with no back ups
- Rate 3: less impact on morale and productivity
- Rate 4: low, little use or effect on output

After overall ratings have been concluded, priority of the works would be determined and the value is varied in the range of 1–64 ( $1 \times 1 \times 1-4 \times 4 \times 4$ ).



According to NUCREC principle, lowest products get the first priority. "Rate 1," is considered as high class emergency. Also, many of the factors are influenced to be selected as first priority but, they can be found using availabilities of labor and materials availability, locations, and scheduling fit. These priorities have been decided in a regular meeting of management. Initially, PM starts with rate 3 and it continuously increases the priority as the weeks passed and the rank will move to 2 and then rank 1. This can be done at the responsible time so that the developments have been found in the organizations.

### iii. Maintenance Scheduling

Maintenance scheduling is the successive arrangements by which repairs have been carried out. It has a following stage like task to be achieved, who will conduct? Where to be carried out? When to be performed? Including necessary activities and estimated accomplishment time. Therefore, procedures of maintenance schedules make the successful preventive maintenance in an organization. Moreover, the amount of work to be determined for each and every craft workers is strictly mentioned by backlogs. This can be achieved by using the following Eq. (3).

The backlog is calculated as:

$$\text{Backlog} = \frac{\text{total pland hour ready to schdule}}{\text{true craft capacity}} \quad (3)$$

where:

Backlog = the amount of work that is documented as needing to be performed by the craft.

True craft capacity = the total hours scheduled for the craft minus scheduled interruptions.

Scheduled interruptions = average hours spent on emergencies, absenteeism, vacations, and routine maintenance work.

An illustrative example for a week with 6 working days 8 hour/day working time and 15 crews (permanent = 10 and contract =5) is:

Total permanent labor hours for next week ( $10 \times 48$  hours) = 480 hours.

Total contract labor for next week ( $5 \times 48$  hours) = 240 hours.

Total over time worked (average from last 3 months) = 60 hours.

Gross labor hours available = 780 hours.

Average emergency work (consider 30% from the last 3 months) = 235 hours.

Average absenteeism/week = 15 hours.

Average routine (non-back log) hours/week = 45 hours.

Average vacation hours/week/ = 05 hours.

Total deductions =300 hours.

Gross minus deduction =  $780 - 300 = 480$  hours.

These 480 hours represent what can really be expected to be completed from backlog work for the week. This number is used to calculate the true backlog as follows. Presume a planned hour to schedule is 3000 hours; the backlog is determined using Eq. (5.1).

$$\text{backlog1} = \frac{3000}{780} = 3.85 \text{ weeks and } \text{backlog2} = \frac{3000}{480} = 6.25 \text{ weeks}$$

The illustrative example shows, it seems that 3.85 weeks are enough to complete the back log but in reality considering the constraints the back log needs 6.25 weeks to accomplish.

iv. Maintenance Control

Maintenance control refers to coordination and allocation of the set of maintenance resources, activities, tools, and procedures utilized to achieve the objectives of the maintenance system. For the successful accomplishment of planned maintenance, it is necessary to establish the mechanism by which each planned maintenance input and output activities are controlled. Maintenance is controlled based on the following major input and output; these are:

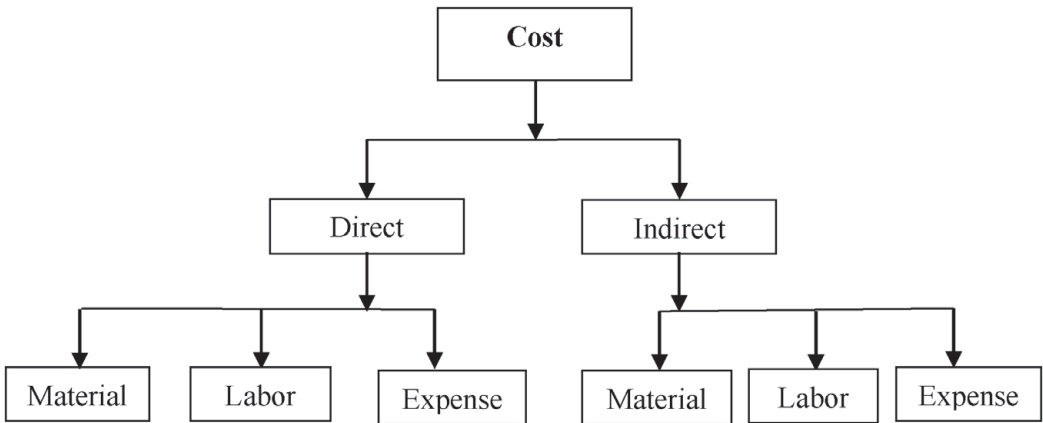
- Cost incurred
- Work control
- Stock control
- Quality and process control
- Performance
- Safety required
- Reporting and feedback system

**Cost controlling:** the most neglected part in maintenance activities conducted in AWF is the cost incurred due to improper maintenance management. Operation department does not stop the work for preventive maintenance purpose for the sake of time saving and short-term profit, respectively. Routine maintenance is not emphasized in the department rather break down maintenance is done. These problems resulted in complex maintenance work, high machine down time, and increased maintenance costs. Maintenance costs to be controlled include:

direct maintenance cost: labor cost and material cost and indirect maintenance costs: down time cost and overhead costs (**Figure 3**).

Successful cost reduction program requires:

- Approval of maintenance work before it is performed
- Planning of maintenance work according to its scope, criticality, cost, etc.
- Prioritized planned work



**Figure 3.**  
Cost category in service and/or production sector (cost center based).

- Scheduling of planned and prioritized work
- Scrutinization of manpower; performance to be measured, and any questionable use of labor being justified by maintenance supervision

**Work control:** deals with monitoring the work status and the accomplished work to investigate if the work is done according to standards (quality and time). To do so, supervisors take responsibility for auditing the maintenance works either the routine maintenance or break down maintenance. To achieve this type of control, it is assumed that the maintenance control system includes standards that are assigned in advance of performing actual maintenance work. Proper planning of man-hours required is necessary to make use of optimum available human resources and implement it accordingly. To increase availability of production machine, use priority order as mentioned above under work order priority analysis.

**Stock control:** stock policies are considered as prior role to reduce the downtime over the selection of materials and parts. Planned maintenance activities are used to enable the giving orders of spare and consumable parts. Having the economic re-order quantities can minimize the inventory, labor cost, and also, plant downtime based upon the usage of the materials. Stock control based on fast moving items and slow moving items in the factory maintenance section is essential under maintenance schedule analysis as discussed in the sub-topic spare part supply.

**Performance control:** performance control can be seen from the technical personnel assigned to conduct the maintenance activities and the equipment maintained point of view. Therefore, it is essential to evaluate the whole system which includes the productivity and service quality of every technician and entire workshop. Moreover, the maintenance management department must consider and include the activities as follows:

**Maintenance costs:** the maintenance cost is inversely proportional to the efficiency of the organization.

**Yearly down time:** the efficiency is reduced when the downtime increases.

**Service life:** if the service life increases, efficiency is also increases.

The overall performance of the organization has been evaluated by cumulating of all mentioned parameters so that the productivity and quality can act accordingly to give promotions and incentives.

**Quality and process control:** the quality of the product has a direct link to the maintenance. Accordingly, effective maintenance gives minimal scrap and also increases the process capabilities. Scrap and repeated jobs are required to record and report by monthly basis to enable for determining the quality of the machines. The corrective action will be taking place after identifying the repaired machines.

**Reporting and feedback system:** maintenance activities need follow-up, reviewing, monitoring, and streamlining of practice (corrective actions) and making continuous improvement to become a genuine part of organizational culture. Maintenance report should be produced every week by maintenance supervisor. The maintenance activities within a week or a couple of weeks should be evaluated by a committee of maintenance workers, maintenance foreman, planners, and production foreman and give solution to the problems and feedback goes to the planner for improvement. It encourages everyone involved in the maintenance process to be responsible for their performance efforts and accomplishments.

## 2. Maintenance program/cycle

Maintenance program/cycle is the maintenance type taking place in chronological order. In other words, maintenance cycle is the period between two

successive major overhauls. Each preventive maintenance program conducted on each machine/equipment comprises maintenance cycles of the machine/equipment. Maintenance programs are inputs for preparation of maintenance plan. Maintenance program is the set of maintenance activities that are planned to be accomplished in a definite interval based on the following factors:

- Manufacture recommendations
- Age of the machinery/equipment/service life of major components
- Operation conditions
- Criticality of the machine or equipment
- Maintenance history of the machine or reported data

The maintenance program/cycle for the washing machine is illustrated as follows:

Type of machine: **BOXY Washer Machine.**

Machine made: **Turkey.**

Machine model: **Mbt0213.**

Purchased date: **May 2013.**

Monthly running/operating hour: 8000 hours.

Total hours to be covered before the first overhaul: 288,000 (5 years).

Preventive maintenance interval: 6000 hours.

Interval of preventive maintenance conducted in month =

$$\frac{\text{Interval of Preventiv Maintenance}}{\text{Monthly running hour}}$$

$$= \frac{6000}{8000} = 0.75\text{month} = 23\text{days}$$

$$\text{Number of maintenance program/cycle} = \frac{\text{total hour in a complet cycle}}{\text{Preventive Maintenance Interval}} = \frac{288,000}{6,000} = 48.$$

Thus, the 48 preventive maintenance programs/cycles for the washer machine to its first overhaul time is **MP1-MP2-MP1-MP2-MP1-MP2-MP1-MP3-MP1-MP2-MP1-MP2-MP1-MP2-MP1-MP2-MP1-MP3-MP1-MP2-MP1-MP2-MP1-MP2-MP1-MP4-MP1-MP2-MP1-MP2 MP1-MP2-MP1-MP3-MP1-MP2-MP1-MP2-MP1-MP2-MP1-MP2-MP1-MP3-MP1-MP2-MP1-MP2-MP1-MP2-MP1-MP5.**

The common activities to be performed on each maintenance program (PM<sub>n</sub>) are listed in **Table 2.**

The 1 year preventive maintenance program proposed to the washer machine operates for 6200 hours and the last maintenance type performed is MP1 at the first position in the cycle as on April 30/2019 is discussed below (**Table 3**).

Determination of maintenance programs, maintenance cycles, and maintenance schedules for each machine or equipment simplify the task of maintenance planning. Maintenance planning can easily be determined (derived) from maintenance programs and maintenance cycles.

Maintenance planning may be prepared for the life of the machine/equipment or working budget year. Annual maintenance plan is recommended to Awash Wine Factory. The annual maintenance plan has to be broken down to quarterly, monthly, weekly, and daily maintenance works to be done. The above maintenance planning samples help the maintenance department to prepare and adopt their annual preventive maintenance plan for other machineries/equipment and instruments according to the criteria already discussed.

Maintenance program	Types of maintenance activities	Period
MP <sub>1</sub>	Clean parts, inspection parts, lubricate necessary parts, clean burner chamber, etc.	Every 6000 hour or 3 weeks whichever comes first
MP <sub>2</sub>	Perform all activities in MP1, check and adjust pump drive belts, inspect and adjust the main chain, etc.	12,000 hour or 1 and half months whichever comes first
MP <sub>3</sub>	Perform all activities in MP2, check and repair: carriers, roller rails, pipes, pump impellers, electric motors	Every 48,000 hour or 10 months whichever comes first
MP <sub>4</sub>	Perform all activities in MP3, check and change: bearings, mechanical seals, bushings	Every 144,000 hour or 2 and half years whichever comes first
MP <sub>5</sub>	Perform PM4, check and change the main chain, check and change the injector, check and change the electric control panels, etc.	288,000 hour or 5 year whichever comes first

**Table 2.**  
*Maintenance activities in a maintenance program.*

PM conducting date	Running hours	PM program	Position/cycle
May 23, 2019	12,000	MP2	2
June 16, 2019	18,000	MP1	3
July 9, 2019	24,000	MP2	4
August 2, 2019	30,000	MP1	5
September 25, 2019	36,000	MP2	6
October 18, 2019	42,000	MP1	7
November 11, 2019	48,000	MP3	8
December 4, 2019	54,000	MP1	9
December 27, 2019	60,000	MP2	10
January 20, 2020	66,000	MP1	11
February 13, 2020	72,000	MP2	12
March 6, 2020	78,000	MP1	13
March 29, 2020	84,000	MP2	14
April 22, 2020	90,000	MP1	15
May 15, 2020	96,000	MP3	16

**Table 3.**  
*Annual maintenance schedule for the washer machine with PMI 6000 hours.*

Maintenance program for other machineries and equipment is left to the maintenance staffs of the factory.

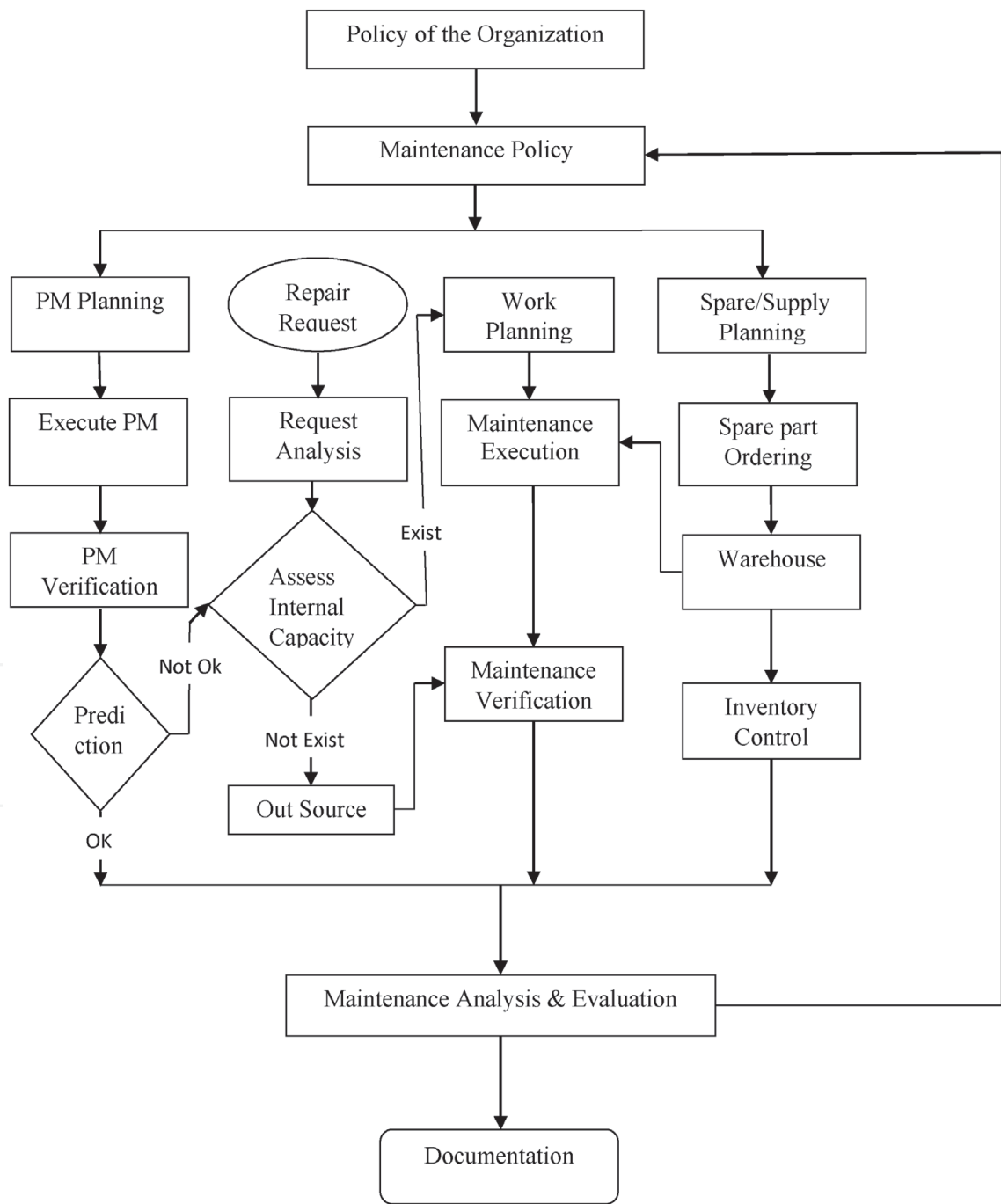
2.1 Maintenance work flow

The success of maintenance organization relays highly on workflow system. For successful accomplishment of maintenance activities, it is necessary to develop and implement a well understood workflow system. This simplifies the task of maintenance and enhances productivity. Thus, for the case company, the suitable work



flow system that should be followed by maintenance planner is proposed in **Figure 4** beneath.

Work orders raised from different departments will be filled on formal work order request form and approved by department manager and submitted to maintenance planner. Therefore, the planner will organize work order from its request formats. Based on the demand, works can move quickly in terms of allocating manpower, arrangement of spare parts to complete the given task effectively. Next work orders released to executors during execution maintenance planners has to follow the progress and quality of work. After completion, the maintenance work should be validated or confirmed for successfulness. This can measure by reworks and/or number of defects. Record keeping is the last stage. It helps to keep histories of machine, measuring performance, and prop up decision making. The



**Figure 4.**  
*Recommended maintenance work flow algorithm.*

recommended workflow model has considered all the requirements of an effective & efficient recent workflow system.

## 2.2 Description

Awash wine factory uses breakdown maintenance strategy with fixed time preventive maintenance management system. That means the machines are maintained according to the maintenance program planned once in a year. But these types of maintenance system is not efficient for such batch production type process, thus preventive maintenance strategy with condition-based maintenance policy is advisable for such industries. The recommended work flow model consists both preventive and reactive work flow system, for the following basic reasons: (1) it is ideal to make an accident free production system, (2) it is difficult to make a complete paradigm shifting of the existing maintenance culture of the plant from breakdown to preventive once, thus breakdown maintenance should be incorporated in the recommended system and gradually changed into pure preventive strategy.

Regularly, preventive maintenance activities have been planned and implemented to each and every machine and equipment in the organization. As a result, the condition of the machine or equipment could be found and hence, the maintenance is decided whether it should be small, medium or high and even some times the maintenance is not required. Accordingly, the feedback is considered to make a plan to work out on good and repaired machineries together. The selection of a part and quantity of the spare parts are to be ordered concurrently to minimize the time to wait for spare parts. Finally, the observations and feedback has been analyzed for the future maintenance and stored safely. The model consists of basic activities to be performed so as to reduce the breakdown time and maintenance cost.

**Preventive maintenance:** at the beginning of every fiscal year, preventive maintenance plans are prepared by maintenance planner discussing with maintenance supervisor, and finally approved by engineering and maintenance manager. Based on the annual plan, preventive maintenance is initiated by assigning an expert/technician. The assigned maintenance crew conducts PM activity on machineries/equipment and identifies the necessary services to be undertaken. Based on the assessment of the assigned maintenance crew, engineering and maintenance manager decides whether internal capacity exists or not. If internal capacity exists for the periodical service, then the assigned maintenance crew will service the machine. If internal capacity does not exist, then engineering and maintenance manager/commercial department head will outsource the service.

Verification is conducted to ensure that the maintenance job is done to prevent the occurrence of potential failures. Maintenance report is prepared indicating the type of service undertaken and the responsibilities allocated at various maintenance stages.

**Corrective maintenance:** Assigned expert/technician conducts inspection on the machine/equipment requested for maintenance and records the findings including:

- The nature of failure
- In-house capability
- Resources needed to undertake the maintenance if internal capability exists
- Availability of spare parts in store and in the market
- If there is a need for modification and other related activates

Based on the assessment of the assigned expert/technician, depending on the machine to be maintained, engineering and maintenance manager decides on whether internal capacity exists or not and other related information with maintenance. If internal capacity exists for the break down maintenance, then the maintenance work is planned and executed. If internal capacity does not exist, then engineering and maintenance manager/commercial department head will outsource the service. Verification is conducted to ensure that the maintenance job is done to prevent the occurrence of potential failures. Maintenance report is prepared indicating the type of maintenance undertaken and the responsibilities allocated at various maintenance stages.

### 3. Computerized maintenance management system

A Computerized Maintenance Management System (CMMS) is a computer software program designed to assist in the planning, management, and administrative functions required for effective maintenance.

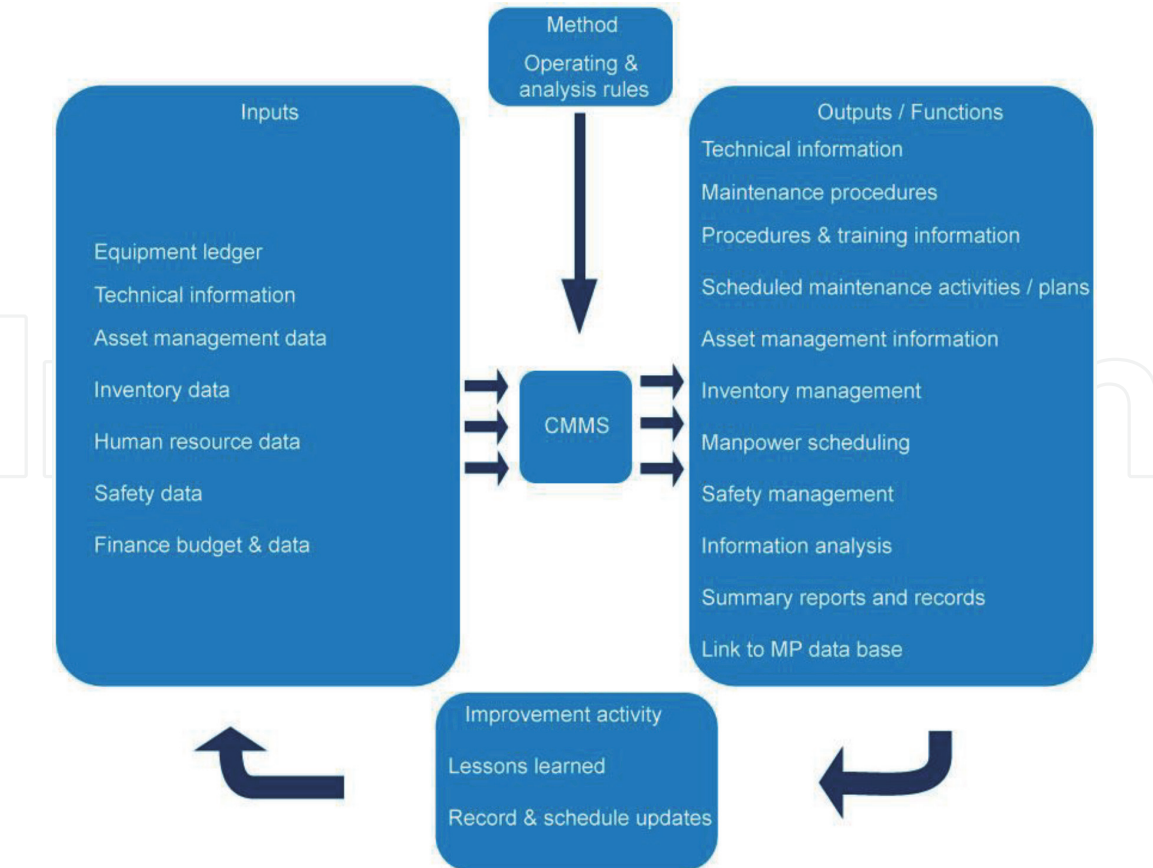
The main challenge of the management maintenance system in the large organization process is complexity, and it has a substantial impact over the entire business. In addition, the process is impossible to maintain or manage effectively without the computerization. Therefore, alternative management program is necessary to achieve successful implementation of the systems in organization.

Functions of computerized system include inputs, methods, outputs, and improvement activities as shown in **Figure 5**.

These functions perform the generating, planning, and reporting of work orders; the development of a traceable history; and the recording of parts transactions. CMMS and their integration into pre-existing organizations have been proven as an excellent platform to promote communications while improving coordination between different functions in the organization. Companies of all sizes can benefit from maintenance software, whether they have a maintenance team of five or five hundred. Users of CMMs can generate the following benefits/advantages:

- **Less work outages:** it is easy to do preventive maintenance/less surprise breakdowns
- **Better accountability:** quick check on one time work done and completion alert
- **Less overtime:** better scheduling; even work distribution; no sitting idle/working overtime
- **Information capture:** recorded problems and solutions, used as information for next task
- **Savings on purchases:** replacement of acceleration time to purchase the spare parts and pricing from the inventory planning features.
- **Certification and analysis:** managers can understand and analyze the total recorded data for the energy usage and utilization of maintenance planning in the company.

Considering the benefits listed above and believing that it is vital to improve the maintenance management in the company, the CMMS software user friendly



**Figure 5.**  
*Process in CMMS (source SMMT industry forum ltd. 2680 king court).*

program with seven entities (*Search Menu, department menu, employees menu, equipment/machinery menu, work requisition menu, task/maintenance work menu and materials or spare parts menu*) is developed to the company.

**4. Objective**

The foremost intention of this study was to enhance productivity of Awash Wine Factory through smart maintenance management system (strategy and management tool). The study focused on the investigation of the existing maintenance problems of the factory and proposed the best solution that increases the reliability of the machinery and then enhances productivity. Consideration is focused on: the maintenance management system to improve the output, machinery condition, operation standards, and reasons for failure, while simultaneously enhances productivity through reducing the downtime of machinery and overall maintenance cost. Hence, in the current chapter took a challenge to develop a model or strategy that will minimize the downtime of the equipment and cost of maintenance. Alternatively, smart maintenance strategy and management system has been developed to enhance the factory’s productivity effectively.

The specific objectives of the study were:

- To assess the existing maintenance system
- To explore and identify the problems in maintenance management system
- To assess the maintenance inventory control mechanism

- To develop preventive maintenance program for critical machinery and/ equipment

### 5. Research design and target population

The research methodology adopted in this study was a descriptive survey type since this research method accurately describes the relation between variables, increase fairness, and maximize the reliability of the data. The method provides straightforward summaries about the sample and the observations that have been made. This ensured that appropriate answers are obtained for the research questions.

The data collecting techniques employed in this work is: subject matter literature surveys using: journal articles, books, related thesis papers; survey questionnaires; unstructured interview questions; visit and assessment of secondary sources such as factory maintenance log book, annual finance reports, published documents, and work order sheets.

The data used in this study have been collected from primary and secondary sources. Primary sources focused on information that helps to have entire understanding of the study through different techniques such as interviews, questionnaires, observations, and discussions, whereas secondary sources of information related to the study have detail understanding with the supportive documents and reports. Both quantitative and qualitative data were collected.

Non-random sampling which is purposive technique was selected in this study because this type of sampling is extremely functional to construct reality, describe a phenomenon or build up an impressive about a universe using specific knowledge. This sampling strategy is feasible to quantitative researches.

The sample for this study is taken from the target population of maintenance department, production department, and management parts of AWF at the two sites (Lideta and Mekanisa)

Population variability, availability of participants, and the suitability to the required information are factors considered when the sample size is determined.

Eqs. (4) and (5) are used to determine the sample size since the population is finite.

$$N = Z^2P(1 - P)/C^2 \tag{4}$$

$$N_s = \frac{N}{1 + \frac{N-1}{N_o}} \tag{5}$$

where N = sample unit (initial sample size)  
Z = value of level of confidence (consider 90% confidence level, Z is 1.645)  
P = percentage picking a choice expressed as decimal 0.5 used for sample size needed  
C = confidence interval expressed as decimal 0.08 = +/- 8%  
Ns = size of targeted sample  
No = size of the population (214 in this study)  
Applying Eqs. (3.1) and (3.2), the target sample size is determined as:  
N = 105 and Ns = 70

### 6. Summary

The first part of the questionnaires presented on the six parameters was discussed in primary data analysis, and the result is summarized as follows:



Regarding the worth given to maintenance, most of the respondents agreed that the attention given to maintenance department is less and it is not considered as a business center rather as a cost center. The budget for maintenance is negligible when compared with other departments. The maintenance management system is outdated, and the scheduling operation plan of maintenance department is poor. The common maintenance action takes place in the company is breakdown based which contributes much for breakdown time increment.

Concerning the intense of the company toward preventive maintenance, the respondents assure that there is a fixed time based preventive maintenance that takes place once in a year regardless of the condition of machines/equipment. However, priority is for reactive maintenance than preventive. While coming to maintenance planning and scheduling, most of the respondents disagreed on the presence of planned and scheduled maintenance. The back log control system, recording and documentation system of the company is said to be meager. The maintenance work is not prioritized technically. The maintenance work recording and documentation system is loyal to mistake and not used as a source for next work. The repair work analysis habit is so poor and needs to be changed. The company puts much effort toward training, and the communication system in the company is committed. The inventory management mechanism is so poor that is why much cost is elapsed when compared with the other maintenance expenses in the company.

The second part of the questioner shows that the frequently failed and bottle-neck machine in the company is washer machine with the production rate of 64.17%. The main causes of the losses in production are stated as mechanical failure in washing section which covers the largest portion (35%), maintenance strategy followed by the plant (27%), maintenance management program (25%), and high cost of maintenance inventory control, and other (13%).

The company has got problems of highest machine breakdown time resulted in a loss of 1,188,950; 1,126,600; 1,174,975 bottles of wine in 2018, 2017, 2016 production year, respectively. In production year 2018, the total product is given by  $(2336 - 116.5) \text{ hour} \times 4300 \text{ bo/hour} = 9,543,850$  bottles. The loss in production in this year is  $(116.5 + 160) \text{ hour} \times 4300 \text{ bot/hour} = 1,188,950$  bottles which is 12.46% of the total product. In addition to production loss, high amount of money is elapsed in maintenance in the stated production years due to the lack of proper maintenance strategy and management system.

## 7. Conclusion

The aim of this study was to enhance productivity of Awash Wine Factory through improved maintenance management system. The basic maintenance problems of the factory were investigated, and smart maintenance system that decrease machine down time and reduce maintenance cost is recommended. Data collected through questionnaires, unstructured interview, visit and document analyses were used to identify the major causes of the problem. Case and effect diagram and failure mode effect and criticality analysis were used as a tool to differentiate the root cause of the problems. The collected data were analyzed by SPSS software, and the following results were obtained. The company has got problems of highest machine breakdown time and high yearly maintenance cost due to wrong maintenance strategy, poor maintenance management system, and repeated failure of washer machine. As a result, the company has lost more than 12% of its yearly product and incurred much money as cost of maintenance.

After the analysis, this study has suggested ways to enhance productivity and increase competitiveness of the factory in the modern market. The recommended maintenance system incorporates preventive maintenance as maintenance strategy

and CMMS as a maintenance management tool with their respective merits explained in the fifth chapter of the study. New annual maintenance program for critical machines like washer machine is developed. The suggested smart maintenance system helps to decrease machine downtimes, increase availability of the machinery, and reduce maintenance costs through the creation of a sense of ownership in each of the plant-equipment operators, maintainers, and support staff so as to encourage “a prevention of problems at source” attitude. Implementing the new maintenance system, the factory will generate many benefits. For instance, considering the present efficiency of the company leaving other factors, the yearly product loss due to machine break down will be reduced from 12 to 6%.

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