ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF MECHANICAL, CHEMICAL AND MATERIAL ENGINEERING

ENHANCEMENT OF MAINTENANCE MANAGEMENT FOR PRODUCTIVITY IMPROVEMENT: A CASE STUDY ON ARMY FOUNDATION ADAMA GARMENT INDUSTRY (AFAGI)

A Thesis Submitted In Partial Fulfillment Of The Requirements For The Award Of The Degree Of Masters Of Science In Manufacturing Engineering

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Enhancement of Maintenance Management for Productivity Improvement: A Case Study on Army Foundation Adama Garment Industry (AFAGI)

By: Yemisrach Dehenanew

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Declaration

I hereby declare that the work which is being presented in thesis entitled "**Enhancement of Maintenance Management for Productivity improvement: Case Study on Army Foundation Adama Garment Industry**." In partial fulfillment of the requirement for the award of the degree of Masters of Science in Manufacturing Engineering is my own work under the supervision of **Dr. Perumalla Janaki Ramulu,** program of Mechanical Design and Manufacturing Engineering, Adama Science and Technology University, Adama, Ethiopia.

The matter embodied in this thesis has not been submitted by me for the award of any other degree or diploma. All relevant resources of information used in this thesis has been duly acknowledged.

Yemisrach Dehenanew _____ _____

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This is to certify that the above declaration made by the candidate is corrected to the best of my knowledge and belief. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master of Science in manufacturing engineering.

Dr. Perumalla Janaki Ramulu _____ _____

Advisor Signature Date

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Abstract

Maintenance Management is an orderly and systematic approach for planning, organizing, monitoring and evaluating maintenance activities and their costs. A good maintenance management system should be coupled with knowledgeable and capable maintenance staff. This will prevent health and safety problems, environmental damages; yields longer asset life with fewer breakdowns; and results in lower operating costs. This research work systematically investigates key factors that negatively affect the effectiveness of maintenance system in Army Foundation Adama Garment industry and improves the maintenance system of the industry through implementation of computer aided maintenance management system.

Understanding the significance of maintenance for machineries, equipment and garment product is very crucial. Accordingly the awareness on the importance of scientific approach towards maintenance management system has been created through discussion. The activities lied on understanding of the existing situation of the industry, identification of key factors that affect maintenance system and related problems and how these problems affect productivity are assessed. Based on results of the assessment a new maintenance strategy has been designed using a special computerized maintenance management system (CMMS) maintenance planning and scheduling software called MP Version 9.

Keywords: factors affecting maintenance management, Effective maintenance system, Computerized Maintenance Management System (CMMS).

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Acronyms

AFAGI Army Foundation Adama Garment Industry

CMMS Computerized Maintenance Management System

MPM Maintenance Performance Measurement

QC Quality Control

ETIDI Ethiopian Textile Industry Development Institute

CBM Condition Based Maintenance

PLC Programmable Logic Controllers

PM Preventive Maintenance

CM Corrective Maintenance

PERT Program Evaluation and Review Technique

CPM Critical Path Method

OEE Overall Equipment Effectiveness

RCM Reliability Centered Maintenance

TPM Total Productive Maintenance

TQM Total Quality Management

ERP Enterprise Resource Planning

CHAPTER ONE

Introduction

1.1 Background of the study

To cope with the tough competition in manufacturing industries, companies have invested in highly automated production system with excellent equipment's. In order to sustain their hold in the global market, proper utilization of equipment's is vital in order to maintain the production operation. Thus leading to the economical sustainability as well as maximization of company profit (Parida, and Kumar, 2006). Whenever sudden downtime occurs, there is disruption it in the production operation. It would be very expensive to revise the production plan in an emergency situation, and also causes lower product quality and variability in service level.

Therefore; Maintenance system plays a crucial role in order to ensure the whole system runs efficiently and effectively (Sharma, et al, 2011). Maintenance is one of the main functions in the manufacturing environment as it more likely to sustain the performance of equipment and improve the operations efficiency in manufacturing plant. Maintenance has been mostly practiced in industries as it gives benefits in term of profit to the company with customer satisfaction. Maintenance which is also known as a profit generator activity, a method to relate with other operation functions as well as to ensure the availability, reliability and safety of all equipment in the plant (Waeyenbergh, and Pintelon, 2002). The main problem faced in this case study was the downtime occurs after maintenance activities were carried out. Therefore, the available schedule of Preventive Maintenance needs to be simplified.

The link between productivity improvement and maintenance is well established. Proper maintenance maximizes the performance reliability 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. That is defects and variations can be eliminated at their source. In particular, machine performance problems are identified early on well-organized maintenance management system. Therefore, one of the main areas for productivity improvement is maintenance and so this were focuses on how to improve the productivity of Army Foundation Adama Garment Industry through effective maintenance management.

This project aimed to prepare maintenance plan and management system using computer based maintenance management software. Finally the conclusions and recommendations are provided for the betterment of company.

1.1.1 Background of the case industry

Army Foundation Adama Garment Industry (AFAGI), having 29 years of history, is the local leading military garments supplier. It was established in 1980E.C under the title name Nazareth canvas sewing and garment factory. It is located at about 105km away from Addis Ababa, on the midway Adama to Wonji town and occupied a total area of 113,500 square meters. The founding aim is to supply modern military clothes that could be computable with the environment and to enhance the readiness for combat of the army by producing military apparel expected to provide fair price, good quality and fast delivery time (sense of regency). The industry has passed through different administrational history. Since transfer to under Army foundation with the title name Adama Garment Industry. The industry structured in three production factories such has:

1. Garment factory;
2. Canvas and Leather product factory and;
3. Weaving and Embroidery product factory.

This industry operates in one shift and five working days. It has 972 employees of which 70% is female. The main customers of the industry are mostly governmental institution like federal police, national defense, industries. Core Business of the Industry is now to Manufacturing of military and commercial (for civil) products like military uniforms, uniforms for many purposes, tents, insignias, different badges engraving products, leather made products, bags, waist belts, car covers etc. The objective of the industry includes Develop technologies that satisfy armed force garment and military requirements and to supply modern apparel at the desire delivery time, quantity, place and quality; perform engineering activities specifically the garment industry. There are three main process sections in each factory. These are cutting, assembling/stitching and finishing, as shown in Figure 1.1 (Army Foundation Adama Garment Industry profile, 2016/17)

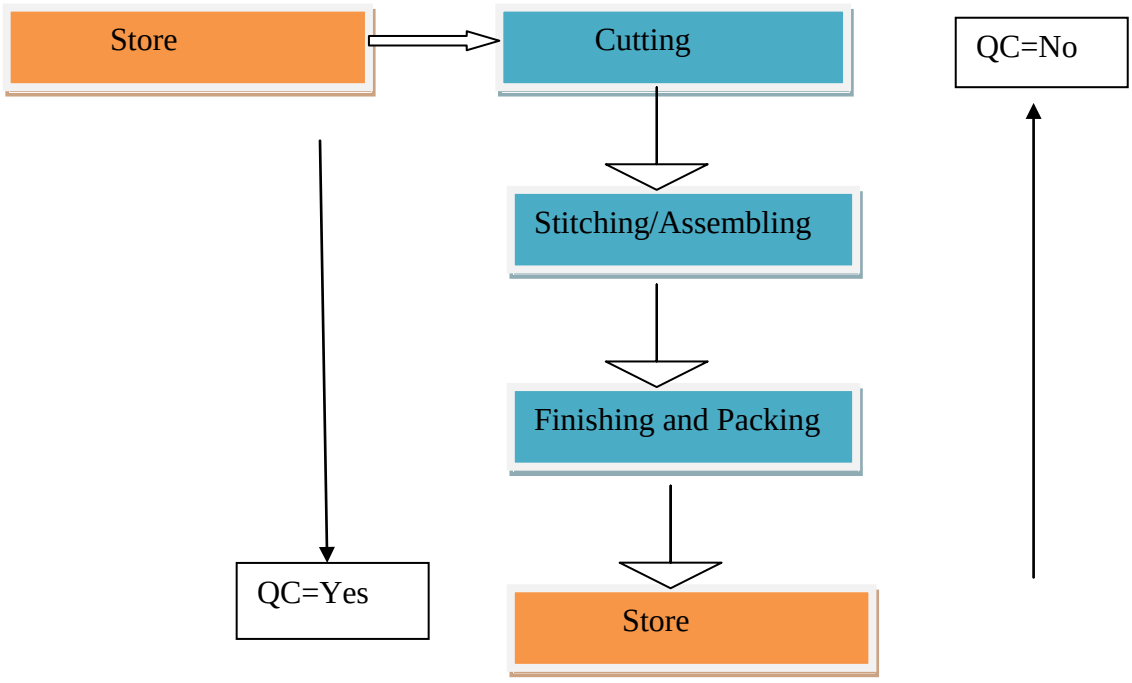

Figure 1.1 Main processes in the case industry

1.1.2 Capital and Number of Employees

The current capital of the AFAGI is Birr 160, 000, 000 (One hundred sixty million Birr) and the current total number of employees of AFAGI is 972. Out of the total employees 925 are permanent and the remaining 47 workers are temporary (short term contract and daily laborers) of which 541 are diploma and above holders, 431 are below diploma (Army Foundation Adama Garment Industry profile, 2016/17)

1.1.3 Organizational Structure of the AFAGI

The Army Foundation Adama Garment Industry (AFAGI) has five departments that directly report to the General Manger. The organizational chart of the industry is presented in Appendix1.

1.2 Motivation of the thesis

Maintenance is a technical discipline, which tries to maximize the performance of machinery and prolong the life of capital equipment. There by, it enables maximum utilization of equipment and high rate of return on investment. It is also related to profitability through equipment output and running cost. Proper maintenance decreases sudden breakdown and increases the revenue of the plant by increasing production output. Maintenance management system comprises evaluation and analysis of indicative control variables such as performance, quality, equipment history and cost, and systematic implementation of programs like planed preventive maintenance, reliability improvement, cost reduction and skill development schemes.

An effective processing and/or manufacturing equipment maintenance program might be characterized as the product of quality. Good maintenance programs and the efficient management systems behind them are essential for economically viable and operationally safe machinery. But during visit, It was observed that Army Foundation Adama Garment Industry lack appropriate equipment maintenance management system. Proper preventive maintenance is one sign of good management system. Preventive equipment maintenance management implies a coherent and formal program of planned repair, component replacement, and servicing activities and the information management system surrounding them, all of which are implemented by an organization to maximize the availability of equipment for operational tasks.

Maintaining equipment productivity is essential to a firm's long-term profitability. The maintenance program may depend on any of a number of strategies such as operate-to-failure or replace-before-failure. In any organizations; for the equipment maintenance program, it should be documented with respect to goals and procedure and should not open to arbitrary changes or interpretations. And once the program is developed and executed it requires continual program assessment to insure long-term performance and profitable.

1.3 Problem Statement

Well maintained production facility will result on more quality product and high production output. In the Army Foundation Adama Garment Industry, this seems to be going differently and the industry awareness for effective maintenance system needs to be improved. The industry

usually focuses on daily/routine activities rather than scheduled maintenance system for the production facilities and is well known for its corrective actions. This has a direct impact on overall productivity of the firm. The existence of computerized maintenance managements system in the textile garment sector is not as it should be. Currently, there is a maintenance system in the factory, where both corrective and preventive maintenance management is adopted to facilitate less failure using the traditional maintenance management system but there are problems in the implementation, control and data management system.

1.4 Objective of the Thesis

1.4.1 General objective

The general objective of this research is to identify factors that affect effectiveness of maintenance system and improve the maintenance management system of Army Foundation Adama Garment industry through use of computer based maintenance management system (CMMS) for critical production equipments of the industry.

1.4.2 Specific Objectives

- ✓ To identify factors that affect maintenance effectiveness.
- ✓ To identify problems related to maintenance management that entangles productivity.
- ✓ Create awareness on importance of scientific maintenance management system within the industry
- ✓ To introduce computer based maintenance management system (CMMS) in to the industry maintenance management system

1.5 Scope of the study

The overall project work activities range from assessment of the current maintenance practice of Army Foundation Adama Garment Industry as a case study and work on analysis of the collected data to reach certain finding in relation to the impact of maintenance system. More over the project will deliver a CMMS based maintenance plan for selected plant machinery. The project did not include the implementation of the prepared plant as a result productivity improvement is not addressed in this document.

1.6 Limitation of the study

The nature of the study mainly depends on the quantity and quality of the collected data, shortage of finance was a limitation to prepare, distribute and collect several questionnaires papers and to extend the research to other similar Garment industries in Adama and other cities.

1.7 Organization of the research

This paper has five chapters; Chapter 1 introduces the background of the thesis, background of the case industry, objective of the paper, problem statements, and scope of the study. Chapter 2 contains maintenance and CMMS concept, the benefit of CMMS which is used as the theoretical background or literature review for the proposed improvement. The Research methodology, how this research is conducted and data collection is described in chapter 3.The data presentation and analysis is discussed in chapter 4.The last chapter, contains findings, conclusions and recommendations, underlined the facts as well as opportunities the industry should attain. The appendices, which present the necessary information concerning the work, are attached at the end of this paper.

CHAPTER TWO

Literature Review

2.1 Concept of Maintenance

According to Sharma and savita (2003) maintenance is considered as set of activities which help keep the plant, machineries and other facilities in good working condition. Harold T. John N.Ritchery addressed maintenance as the function of manufacturing management that is concerned with the day to day problem of keeping the physical plan in a good operation condition.

A maintenance strategy involved the identification. Researching and execution of many repair, replace and inspect decisions (Kelly, 1997). A maintenance concept can be defined as the set of various maintenance interventions (corrective, preventive, condition based, etc.) and the general structure in which these interventions were foreseen (Pintelon and Waeyenbergh, 1999).

Several maintenance approaches, i.e. strategies and concepts, developed and implemented through the evolution of maintenance. The maintenance was emerged from failure based maintenance, and moved towards preventive and is now realized in the essence of process oriented ‘‘holistic’’ approach (Alsyouf, 2007). Likewise, Waeyenbergh and Pintelon, 2002) argued that maintenance has shifted from failure based towards condition based maintenance (CBM) (et al, 2014). Maintenance is a function in an organization that operates in parallel with production. It is a technical discipline, which tries to maximize the performance of machinery and prolong the life of capital equipment. The primary output of production is the desired product and its secondary output is demand for maintenance, which is in-turn an input for the maintenance function. Maintenance results in a secondary input to production in the form of production capacity. While production manufactures the product, maintenance produces the capacity for production. Therefore maintenance affects production by increasing production capacity and controlling the quality and quantity of output.

Production capacity of the system is reduced by the machines idled by failures or breakdowns. Poor maintenance leads to increased production costs. A machine breakdown increases the labor costs per unit product due to an idle labor. Preventive maintenance refers to maintenance action

performed to keep or retain machine/equipment or asset in satisfactory operating condition through periodic inspections, lubrication, calibration, replacements and overhauls. And hence preventive maintenance attempts to prevent any probable failures or breakdowns resulting in production stoppages. As the amount of production capacity is directly related to performance of machineries and equipment's, preventive maintenance will affect the productivity of the machineries and equipment's. (Sharma and Savita, 2003).

2.2 Types of maintenance Programs

There are six types of maintenance philosophy that determines the amount of service required from the equipment and resultant cost. They are discussed below: (Terry Wireman, 1990).

1. Breakdown maintenance: - is just what its name implies - the equipment is run until it breaks down or its performance is unacceptable. It is also called Run-to-failure maintenance. There is no preventive maintenance; the technicians work only on equipment that is malfunctioning. This is the most expensive way to do maintenance. Equipment service level is below acceptable levels with impacted product quality. Equipment is never taken offline for maintenance. It allows for a lower skill set, as the failure is well defined. There is no requirement to purchase extra parts or labor, because no maintenance actions between failures. Unfortunately, failures occur at the most inopportune times, and severely disrupt production. Repairs are expensive emergencies because there is no resource planning. Parts require express shipment and overtime costs are high.

2. Minor lube programs: - are one step removed from breakdown maintenance programs. The equipment still is not overhauled until it breaks down, except that with the lube program it takes longer for the equipment to break down. Unfortunately, many companies mistake the lube program as a preventive maintenance program. Equipment service level is still not satisfactory under this program.

3. Preventive maintenance: - is any planned maintenance activity that is designed to improve equipment life and avoid any unplanned maintenance activity. It includes the lubrication program plus routine inspection, cleaning and adjustments. These service steps take care of small problem before they cause equipment outage. With this maintenance, equipment service levels

begin to enter the acceptable range for most operations. Thus this type of maintenance allows many potential problems to be corrected before they occur.

4. Predictive maintenance: - another type of preventive 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.

5. Condition-based maintenance: - is maintenance performed, as it is needed, with the equipment monitored continually. The main point being that the assets condition is assessed under operation with the intention of making conclusions to whether it is in need of maintenance or not and if so at what time does the maintenance actions needs to be executed not to suffer a breakdown or malfunction. The degree of automation in assessing the condition can vary from human visual inspection to fully automated systems with sensors, data manipulation, condition monitoring, diagnosis, and prognosis. Some modern plants have the PLCs (Programmable Logic Controllers) wired directly to a computer to monitor the equipment condition in a real time mode. Any deviation from the standard normal range of tolerances will cause an alarm (or, in some situations, a repair order) to be generated automatically. This real time trending allows for the maintenance to be performed in the most cost effective manner. This is the optimum maintenance cost versus equipment service level method available. However, the start-up and installation costs are very high.

6. Zero failure maintenance: - is used in any environment where the cost of a failure and the resulting production outage is very high. This type of maintenance combines several of the prior techniques. To produce a maintenances environment, all critical points on equipment and processes are monitored in a real time mode with the data being charted and trended as to the service life of each item. When the equipment or process becomes questionable, it is taken off-line and repairs are made; the equipment or process is then returned to service. While this type of maintenance is sophisticated, it is also the most expensive. It is only used in processes where the cost can be highly justified.

2.3 Elements of Effective Maintenance Management

There are many elements of effective maintenance management whose effectiveness is the key to the overall success of the maintenance activity. Many of these elements are described below. (Dhillon, B.S, 2002)

2.3.1 Maintenance Policy

A maintenance policy is one of the most important elements of effective maintenance management. It is essential for continuity of operations and a clear understanding of the maintenance management program, regardless of the size of a maintenance organization. Usually, maintenance organizations have manuals containing items such as policies, programs, objectives, responsibilities, and authorities for all levels of supervision, reporting requirements, useful methods and techniques, and performance measurement indices. Lacking such documentation, i.e., a policy manual, a policy document must be developed containing all essential policy information.

2.3.2 Material Control

Past experience indicates that, on average, material costs account for approximately30 to 40% of total direct maintenance costs. Efficient utilization of personnel depends largely on effectiveness in material coordination. Material problems can lead to false starts, excess travel time, delays, unmet due dates, etc. 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.

2.3.3 Work Order System

A work order authorizes and directs an individual or a group to perform a given task. A well-defined work order system should cover all the maintenance jobs requested and accomplished, whether repetitive or one-time jobs. The work order system is useful for management in controlling costs and evaluating job performance.

Although the type and size of the work order can vary from one maintenance organization to another, a 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 (preventive maintenance, repair, installation, etc.), and appropriate approval signatures.

2.3.4 Equipment Records

Equipment records play a critical role in effectiveness and efficiency of the maintenance organization. Usually, equipment records are grouped under four classifications: maintenance work performed, maintenance cost, inventory, and files. The maintenance work performed category contains chronological documentation of all repairs and preventive maintenance (PM) performed during the item's service life to date. The maintenance cost category contains historical profiles and accumulations of labor and material costs by item. Usually, information on inventory is provided by the stores or accounting department. The inventory category contains information such as property number, size and type, procurement cost, date manufactured or acquired, manufacturer, and location of the equipment/item. The files category includes operating and service manuals, warranties, drawings, and so on.

Equipment records are useful when procuring new items/equipment to determine operating performance trends, troubleshooting breakdowns, making replacement or modification decisions, investigating incidents, identifying areas of concern, performing reliability and maintainability studies, and conducting life cycle cost and design studies.

2.3.5 Preventive and Corrective Maintenance

The basic purpose of performing PM is to keep facility/equipment in satisfactory condition through inspection and correction of early-stage deficiencies. Three principle factors shape the requirement and scope of the PM effort: process reliability, economics, and standards compliance. A major proportion of a maintenance organization's effort is spent on corrective maintenance (CM). Thus, CM is an important factor in the effectiveness of maintenance organization.

2.3.6 Job Planning and Scheduling

Job planning is an essential element of the effective maintenance management. A number of tasks 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, coordination with other departments, and securing safety permits.

Although the degree of planning required may vary with the craft involved and methods used, past experience indicates that on average one planner is required for every twenty craft persons. Strictly speaking, formal planning should cover 100% of the maintenance workload but emergency jobs and small, straightforward work assignments are performed in a less formal environment. Thus, in most maintenance organizations 80 to 85% planning coverage is attainable.

Maintenance scheduling is as important as job planning. Schedule effectiveness is based on the reliability of the planning function. For large jobs, in particular those requiring multi-craft coordination, serious consideration must be given to using methods such as Program Evaluation and Review Technique (PERT) and Critical Path Method (CPM) to assure effective overall control.

2.3.7 Backlog Control and Priority System

The amount of backlog within a maintenance organization is one of the determining factors of maintenance management effectiveness. Identification of backlogs is important to balance manpower and workload requirements. Furthermore, decisions concerning overtime, hiring, subcontracting, shop assignments, etc., are largely based on backlog information. Management makes use of various indices to make backlog related decisions.

The determination of job priority in a maintenance organization is necessary since it is not possible to start every job the day it is requested. In assigning job priorities, it is important to consider factors such as importance of the item or system, the type of maintenance, required due dates, and the length of time the job awaiting scheduling will take.

2.3.8 Performance Measurement

Successful maintenance organizations regularly measure their performance through various means. Performance analyses contribute to maintenance department efficiency and are essential to revealing the downtime of equipment, peculiarities in operational behavior of the concerned organization, developing plans for future maintenance, and so on**.**

2.4 Maintenance Planning and Scheduling

2.4.1 Strategic Planning in Maintenance

Traditionally, maintenance is not viewed as a strategic unit in the organization and hence maintenance planning was mostly done at midterm range. However, the strategic dimension of the maintenance function has lately drawn the attention of the researchers and practitioners with the increase in the competition at a global level and with the increase of the maintenance cost relative to other costs in the organization. Equipment availability, especially in certain business sectors like energy generation and oil exploration and other mega projects, is becoming a major concern because of its high cost of acquisition. Emerging operational strategies such as lean manufacturing are shifting the emphasis from volume production to quick response, defect prevention and waste elimination. These changes in operations strategies require changes in maintenance strategies related to equipment and facility selection and optimizing the maintenance activities with respect to the new operations objectives. Rapid technological changes in nondestructive testing, transducers, vibration measurement, thermograph, and other emerging technologies generated an alternative strategy of condition based maintenance. However, these new technologies introduced new challenges that maintenance systems have to face including the development of new capabilities and management practices to utilize these technologies. Plans have to be developed at a strategic level for keeping up with emerging technologies in the long run.

These changes in the business environment developed the realization that maintenance must not be viewed only in the narrow operational context dealing with equipment failure and their consequences. Rather it must be viewed in the long term strategic planning context that integrates technical and commercial issues as well as changes in the sociopolitical trends.

Maintenance must be viewed strategically from the overall business prospective and has to be handled within a multidisciplinary approach. (Socio political,Murthy et al,2002))

It deals with strategic issues such as outsourcing of maintenance and the associated risks and other related issues. Murthy et al. (2002) described the strategic view of maintenance by the equipment state, the operating load, maintenance actions (strategies) and business objectives. The state of the equipment was affected by the operating load as well as the maintenance actions. The operating load is dependent on the production plans and decisions which are in turn effected by commercial needs and market consideration. Therefore, maintenance planning has to take into consideration the production planning, maintenance decisions, equipment inherited reliability and market and commercial requirements. The model is shown in Figure 2.1

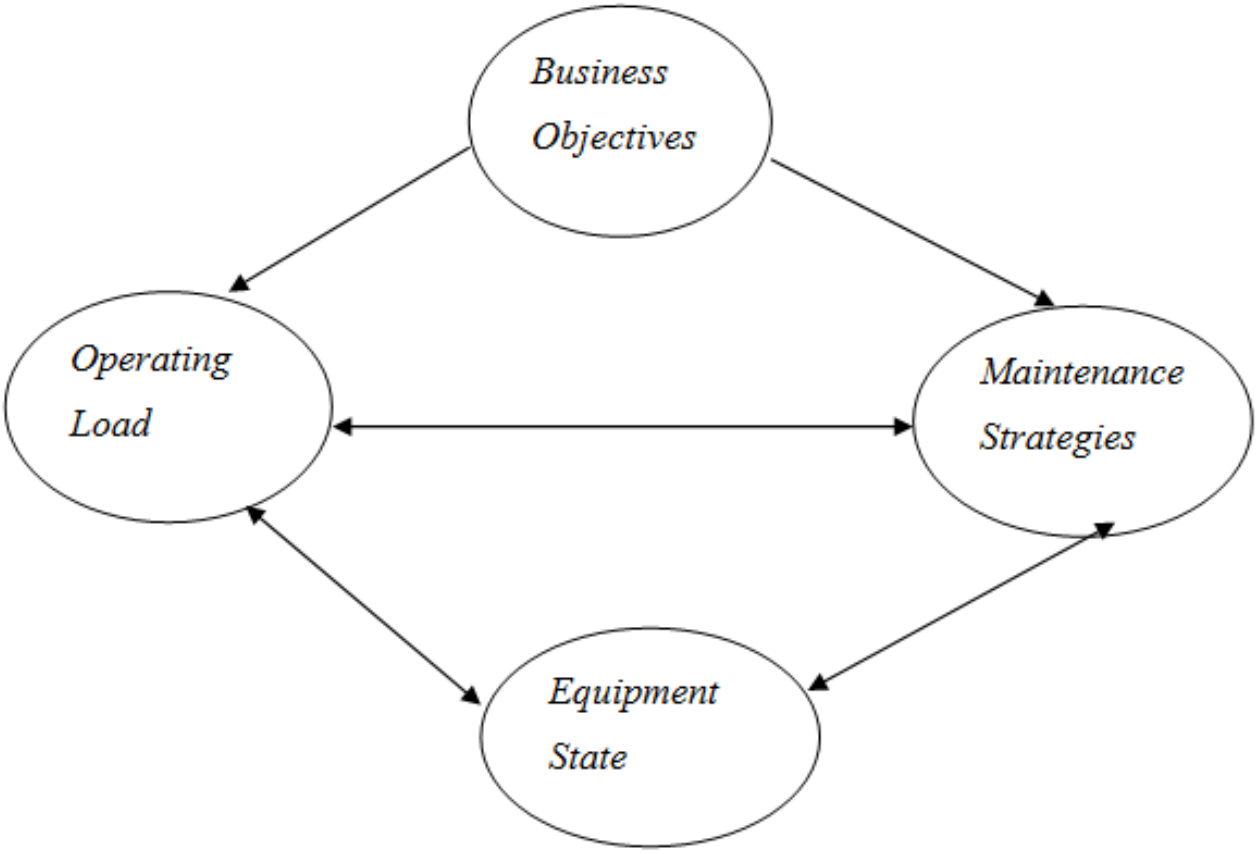

Figure 2-1 Key elements of strategic maintenance management Source: Murthy et al. 2002

There are different alternative methodologies for the strategic planning process. All of them stress the involvement of all stakeholders in the process through brain storming sessions and focused group meetings. One possible methodology comprise of the following steps: Figure 2.2 The maintenance planning process

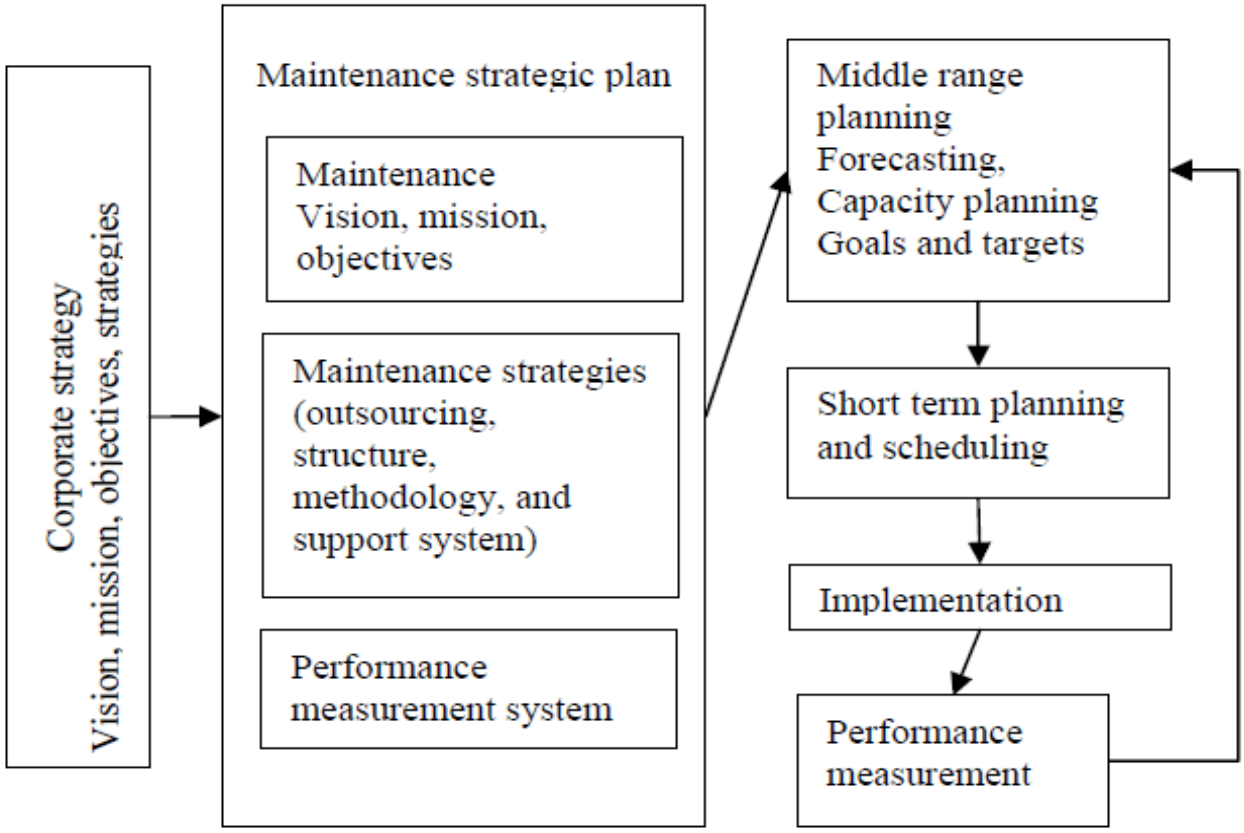

Figure 2-2The maintenance planning process Source: **Murthy et al. 2002**

2.4.2 Medium Range Planning

The medium range plan covers a period of 1 month to 1 year. The plan specifies how the maintenance force operates and provides details for major overhauls, construction jobs, preventive maintenance plans, plant shutdowns, and vacation planning. A medium range plan balances the need for manpower over the period covered and estimates the required spare parts and material acquisition. Medium range planning needs utilization of the following methods:

1. Sound forecasting techniques to estimate the maintenance load;

2. Reliable job standard times to estimate manpower requirements; and

3. Aggregate planning tools such as linear programming to determine optimum resource requirements.

For planning purposes maintenance work can be classified into the following five categories:

1. Routine and preventive maintenance, which includes periodic maintenance such as lubricating machines, inspections and minor repetitive jobs. This type of work is planned and scheduled in advance.

2. Corrective maintenance, which involves the determination of the causes of repeated breakdowns and eliminating the cause by design modification;

3. Emergency or breakdown maintenance is the process of repairing as soon as possible following a reported failure. Maintenance schedules are interrupted to repair emergency breakdowns.

4. Scheduled overhaul, which involves repairs or building of equipment which does not fall under the above categories. The maintenance management system should aim to have over 90% of the maintenance work to be planned and scheduled in order to reap the benefits of planning and scheduling.

2.4.3 Short Range Planning

Short range planning concerns periods of 1 day to 1 week. It focuses on the determination of all elements required to perform industrial tasks in advance. Short range planning in the context of maintenance means the process by which all the elements required to perform a task are determined and prepared prior to starting the execution of the job. The maintenance work order does not usually provide enough space to perform the details of planning for extensive repairs, overhauls or large maintenance projects. In such cases where the maintenance job (project) is large and requires more than 20 h, it is useful to fill a maintenance planning sheet. An example of such a sheet is given in Table 2.1. Maintenance planning sheets were found useful in planning the maintenance of freight cars in railways, when the cars arrive for their six month scheduled preventive maintenance. In the maintenance planning sheet the work is broken down into

elements. For each element the crew size and the standard times are determined. Then, the content of the planning sheet is transferred in one or several work orders. In filling the planning sheet or the work order the planner must utilize all the expertise available in the maintenance department. Thus consultations with supervisors, foremen, plant engineers and crafts should be available and very well coordinated.

Therefore the planning and scheduling job requires a person with the following qualifications:

- Full familiarity with production methods used through the plant;
- Sufficient experience to enable him to estimate labor, material and equipment needed to fill the work order;
- Excellent communication skills;
- Familiarity with planning and scheduling tools; and
- Preferably, with some technical education.

The planner office should be centrally located and the office organization depends on organization size.

2.4.4 Maintenance Scheduling

Maintenance scheduling is the process by which jobs are matched with resources (crafts) and sequenced to be executed at certain points in time. The maintenance schedule can be prepared in three levels depending on the horizon of the schedule. The levels are: (1) medium range or master schedule to cover a period of 3 months to 1 year; (2) weekly schedule, it is the maintenance work that covers a week; and (3) the daily schedule covering the work to be completed each day.

The medium range schedule is based on existing maintenance work orders including blanket work orders, backlog, preventive maintenance, and anticipated emergency maintenance. It should balance long term demand for maintenance work with available manpower. Based on the long-term schedule, requirements for spare parts and material could be identified and ordered in advance. The long range schedule is usually subjected to revisions and updating to reflect changes in plans and realized maintenance work.

The weekly maintenance schedule is generated from the medium range schedule and takes account of current operations schedules and economic consideration. The weekly schedule should allow for about 10–15% of the workforce to be available for emergency work. The planner should provide the schedule for the current week and the following one, taking into consideration the available backlog. The work orders that are scheduled for the current week are sequenced based on priority. Critical path analysis and integer programming are techniques that can be used to generate a schedule. In most small and medium sized companies, scheduling is performed based on heuristic rules and experience.

The daily schedule is generated from the weekly schedule and is usually prepared the day before. This schedule is frequently interrupted to perform emergency maintenance. The established priorities are used to schedule the jobs. In some organizations the schedule is handed to the area foreman and he is given the freedom to assign the work to his crafts with the condition that he has to accomplish jobs according to the established priority. Table 2.1 an example of a maintenance planning sheet. (Mohamed Ben-Daya et al, 2009).

Table 2-1 An example of a maintenance planning sheet

		Field by----------			*Date*----------	
Equipment #		*Approval*----------			*Priority* *Normal* ☐ *Scheduled* ☐	
No.	*Completion Date*	*Work order #*	*Unit*	*Work description*	*Crafts*	*Estimated time*

Source: Mohamed Ben-Daya, 2009

2.5 Effective Programs for Improving Maintenance Control

In this section, four engineered maintenance programs are briefly outlined. These programs offer sound courses of action that can be adopted to enhance maintenance control. The objective of these programs is to improve plant availability, reduce cost, and improve OEE (Overall Equipment Effectiveness) and product quality. These programs are listed below:

1. Emergency maintenance;

2. Reliability improvement;

3. Total productive maintenance; and

4. Computerized maintenance management.

2.5.1 Emergency Maintenance

Emergency maintenance refers to any job that should be attended to immediately. Emergency maintenance, by its nature, allows very little lead time for planning. The amount of emergency maintenance must be minimized and it should not exceed 10% of the total maintenance work. The maintenance department must have a clear policy for handling emergency maintenance. One of the following offers an approach to handling emergency maintenance:

1. Preempt the regular schedule and perform the emergency maintenance, then pick up the backlog with overtime, temporary workers or contract maintenance; and

2. Assign dedicated crafts for emergency maintenance based on the estimated emergency maintenance load. It is an accepted practice in industry to allow 10–15% of load capacity for emergency work. The first approach is expected to result in increased workforce utilization;

However, the second approach offers the ability to respond quickly as needed.

2.5.2 Reliability Improvement

A reliability engineering program offers a sound alternative for improving the maintenance function. It can be used as an option to improve maintenance performance. Critical and major equipment history files must be maintained and estimates for mean time between failure (MTBF) must be calculated. The frequency of emergency maintenance is a function of the failure rate of this equipment. It can be estimated for a period of operations lasting n hours, there will be

n/MTBF emergency maintenance actions. The longer the MTBF the lower the number of emergency maintenance incidents. Reliability centered maintenance (RCM) can be utilized to enhance maintenance polices and improve equipment reliability. In RCM, the maintenance program is developed on the basis of the concept of restoring equipment function rather than bringing the equipment to an ideal condition. RCM has been applied successfully in the commercial airline industry, nuclear reactors, and other power plants.

2.5.3 Total Productive Maintenance

Total Productive Maintenance (TPM) is an approach to maintenance developed in Japan that brings the tools of total quality management (TQM) to maintenance. The aim of TPM is to reduce six categories of equipment losses to improve overall equipment effectiveness (OEE). The six major causes of equipment losses, according to Nakajima (1988) are:

1. Failure;
2. Set-up and adjustments;
3. Idling and minor stoppage;
4. Reduced speed;
5. Process defects; and
6. Reduced yield.

TPM empowers operators and uses multi-skilled crafts to minimize response time and perform productive maintenance. The implementation is expected to assist in improving maintenance effectiveness and control.

2.5.4 Computerized Maintenance Management and Information Technology

Highly technical production units (machinery/equipment) require high technology maintenance and control systems, so maintenance systems must move in new directions if manufacturers/service enterprises hope to keep that expensive production/service equipment up and running. Information technology hardware and software enable maintenance management to automate and process activities in a speedy manner. Above all enable maintenance managers to retrieve and process information that can be used for effective maintenance planning and control. Every company must use a basic computerized maintenance system. It is most effective to

integrate such systems with organization enterprise resource planning (ERP). Many of the existing ERPs have maintenance modules.

Finally, any system that is installed should serve the maintenance personnel rather than forcing these people to serve the system, so all such systems will require extensive personnel training. (Mohamed Ben-Daya, 2009)

2.6 Maintenance and production

The main task of production is to produce goods/ products. Nevertheless, efficient maintenance policy influences production capacity of machine used for producing these products. Maintenance therefore can be considered as an organizational function that functions in parallel with production. While reiterating that production produce product, the authors also express that maintenance produces the capacity for production. Thus, it can be said that maintenance affects production by increasing production capacity while also controlling the output quantity and quality (Ben-Daya and Duffuaa, 1995).

The primary output of production is the desired product and its secondary output is demand for maintenance, which is in turn an input for the maintenance function (Ben-Daya and Duffuaa, 1995). Hence, a strong maintenance program is needed to provide reliable equipment maintenance and reduce equipment process variation (McKone et al., 2001). Therefore, maintenance major role should be maintaining the quality of the elements involved in production instead of just jumping from one repair to another similar to fir men, according to Al-Najjar (2007). Also, it affects production by increasing production capacity and controlling the quality and quantity of output. When outlining the link between quality and maintenance, is also necessary to indicate that product quality, production cost, machine condition and its life length are not just influenced by the type of production machinery and maintenance policy, but also by the quality of the input of elements (such as raw material, production tools, methods and procedures, operating and maintenance staff competence and operating conditions) in the production process (Ibid).

As noted earlier quality defects and rework are losses in quality caused by malfunctioning production equipment. According to Nakajima (1998) losses related to availability, performance efficiency, and quality rate are: (1) Equipment failure/breakdown losses, (2) Setup/ adjustment

time losses, (3) Idling and minor stop losses, (4) Reduced speed losses, (5) Reduced yield, (6) Poor productivity due to poor quality. In a case study Alsyouf (2007), found that loss of production because of unavailability due to all types of unplanned stoppages and losses related to maintenance problems resulted in reduced productivity. Hence, reducing production losses and enhancing product quality always yield more profit improvement in the company's competitiveness, (Al-Najjar and Alsyouf, 2003),especially through detecting and eliminating causes of problems at early stages (Al-Najjar,1996). (Maletic, D., Maletic, M., Al-Najjar, B. and Gomiscek,B, 2014).

Productivity and its linkage with maintenance management

Productivity is the amount of output produced per unit of input. In other word it is the reduction of waste of resources or connected with optimal utilization of inputs (resources) i.e. machine, materials, energy, space, time and building for producing products or services. Despite the fact that production can be increased by increasing input, the productivity may not increase.

The inter-relation between maintenance, maintenance management, production capacity and productivity can be shown in Figure 2.3

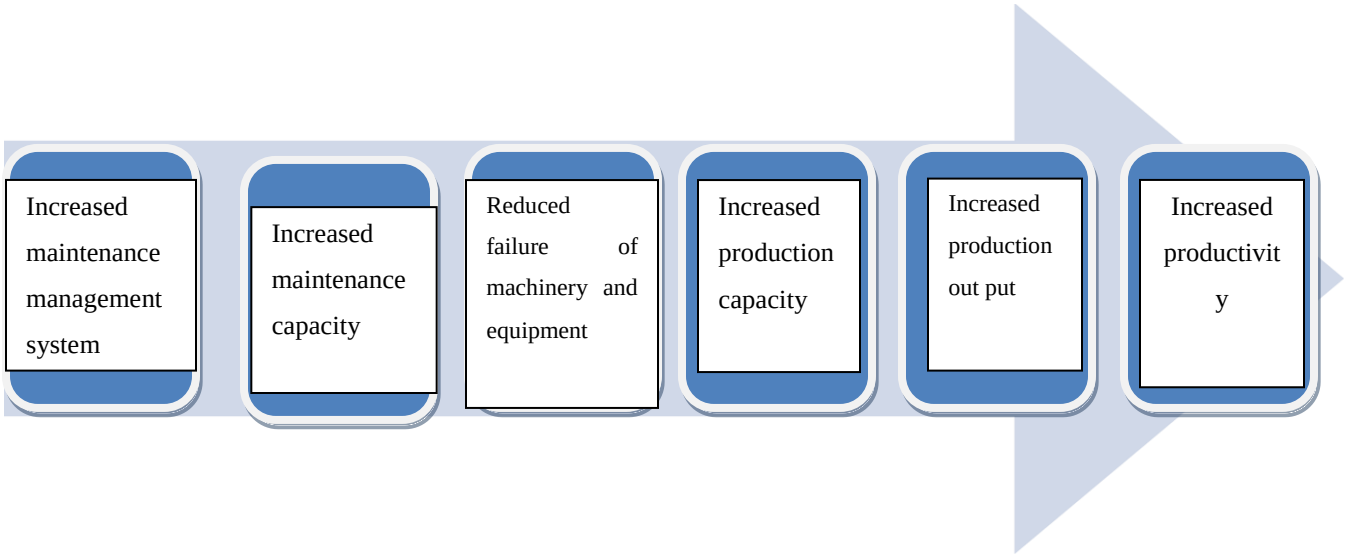

Figure 0-3 The inter-relation between maintenance, maintenance management, production capacity and productivity

2.7 Productivity concept

Productivity is an overall measure of the ability to produce a good or service. Productivity may also be defined as an index that measures output (goods and services) relative to the input (labor, materials, energy, etc., used to produce the output). There are two major ways to increase productivity: increase the numerator (output) or decrease the denominator (input). A similar effect would be seen if both input and output increased with output increasing faster than input; or if both input and output decreased with input decreasing faster than output. A productivity ratio can be computed for a single operation, a department, a facility, an organization, or even an entire country.

Productivity is an objective concept, which can be measured, ideally against a universal standard. As such, organizations can monitor productivity for strategic reasons such as corporate planning, organization improvement, or comparison to competitors. It can also be used for tactical reasons such as project control or controlling performance to budget.

Productivity is useful as a relative measure of actual output of production compared to the actual input of resources, measured across time or against common entities. As output increases for a level of input, or as the amount of input decreases for a constant level of output, an increase in productivity occurs. Therefore, a "productivity measure" describes how well the resources of an organization are being used to produce output.

Productivity is often confused with efficiency. Efficiency is generally seen as the ratio of the time needed to perform a task to some predetermined standard time. However, doing unnecessary work efficiently is not exactly being productive. It would be more correct to interpret productivity as a measure of effectiveness (doing the right thing efficiently).

(Coelli, Timothy J., D.S. Prasada Rao,Christopher O'Donnell, and George Battese. 2nd Ed. New York: Springer 2005).

2.7.1 Factors Affecting Productivity

There is quite a variety of factors that can affect productivity, these include:

- ✓ Capital investments in technology and equipment
- ✓ Capital investments in facilities
- ✓ Economies of scale
- ✓ Workforce knowledge and skill resulting from training and experience

- ✓ Technological changes
- ✓ Work methods and procedures
- ✓ Systems
- ✓ Quality and reliability of suppliers
- ✓ Quality of management
- ✓ Legislative and regulatory environment (Coelli, Timothy J., D.S. Prasada Rao,Christopher O'Donnell, and George Battese. 2nd Ed. New York: Springer 2005).

2.7.2 Improving Productivity

Improvement may be realized through improved methods, investment in machinery and technology, improved quality, and improvement techniques and philosophies such as just-in-time, total quality management, lean production, supply chain management principles, and theory of constraints.

A firm or facility may undertake a number of key steps toward improving productivity:

- Develop productivity measures for all operations; measurement is the first step in managing and controlling an organization.
- Look at the system as a whole in deciding which operations are most critical; it is overall productivity that is important.
- Develop methods for achieving productivity improvement, such as soliciting ideas from workers (perhaps organizing teams of workers), studying how other firms have increased productivity, and re-examining the way work is done.
- Establish reasonable goals for improvement.
- Provide management support and encouragement.
- Measure improvements and publicize them. (Coelli, Timothy J., D.S. Prasada Rao,Christopher O'Donnell, and George Battese. 2nd Ed. New York: Springer 2005).

2.8 The concept of Computerized Maintenance Management System

A computerized maintenance management system (CMMS) is an integrated set of computer programs and data files designed to provide its user with a cost effective means to manage a massive amounts of data that are generated by maintenance and inventory control organizations. The objectives of CMMS is to improve maintenance costs, reduced device's downtime as a result

of scheduled preventative maintenance, increased device's life, ability to store historical records to assist in the planning and budgeting of maintenance and ability to generate maintenance reports. (Rami Hikmat Fouad1 Mohammed Rawashdeh2, Adnan ALBashir2 &Bassam AL-Sharif, 2012)

Benefits of Computerization

With increased availability and affordability of computer resources, the benefits of computerization are becoming accessible to more areas of the plant and factory. Although the functions performed and the advantages promised vary, in general the benefits of computer-automated maintenance can be classified into four basic types: (Rami Hikmat Fouad1 Mohammed Rawashdeh2, Adnan ALBashir2 &Bassam AL-Sharif, 2012)

- Reduced costs
- Greater access to information
- Better planning and
- Increased control

Reduced Costs. The oldest and most frequently cited benefit of computerization is lower cost, either because the same work can be done with less effort, or because more work can be done with the same effort. Either way, the computer cuts the cost per unit of work accomplished, saving the plant money.

Manually intensive functions requiring repetitive clerical tasks are obvious opportunities for this type of computer solution. Typing work orders, for example, can be streamlined with word processing capabilities that store standard documents and enable changes to be made simply by typing the revisions. The result is that more work orders can be produced by the typist, thereby lowering the cost.

Computerization also beneficially affects maintenance work itself. Using the computer as a job planning tool improves the efficiency of the planner, reduces errors, and can even streamline the maintenance work itself. Standard job plans can be stored on computer disk and easily modified for the specific circumstances of the job. The computer cuts the planner’s time and, because the standard plan has all the parts and tools identified for successfully performing the maintenance

job, ensures that the job is done right and with a minimum of backtracking to get forgotten items. The computer can also be used to determine the most cost-effective preventive maintenance interval, to efficiently manage inventories of parts and stores, and to reduce the expense of training new personnel.

Greater Access to Information. Often, useful—perhaps even invaluable—information is either unavailable or very cumbersome and time-consuming to obtain. The computer can help make information readily accessible by storing data in retrievable form and by facilitating data manipulation and reporting. Information can be obtained on a regular basis in the form of periodic reports, but it can also be accessed or provided on an ad hoc basis from a computer screen.

Data-management software, in conjunction with high-speed computer disk drives, can easily maintain large databases which are widely accessible and provide a wide range of useful information in a user-selected format. A database of plant equipment, for example, can easily and quickly be interrogated for answers to questions such as:

- Which machines (by machine number and location) were built by the same manufacturer?
- Which parts (by manufacturer and part number) are shared by multiple machines?
- Which machines (by area, function, and machine number) are due for preventive maintenance?

In addition, by adding data on repairs and maintenance, this same database could provide a complete machine history with information on the frequency, timing, and cost of maintenance.

Better Planning. Greater access to information, coupled with the speed and flexibility of the computer, enables maintenance management to do a better job of planning and coordinating their efforts. Regular planning tasks, such as budgets and manpower plans, as well as nonrecurring plans, such as preventive-maintenance interval determination and inventory-reordering point analysis, can be Stream lined and improved significantly. Plans are quickly constructed. Changes are easily accommodated. More versions can be tested and evaluated before a final approach is accepted.

The computer is also a powerful tool for simulating a proposed plan so that unanticipated flaws can be ironed out prior to implementation.

Increased Control. The combination of these benefits leads to a further benefit of computerization: increased control over maintenance operations. Streamlining manual, clerical tasks; accessing information heretofore impossible to obtain quickly and easily; and better operations planning result in improved management control of day-to-day functions. With these resources, the plant or maintenance engineer is better informed and better able to take action before problems arise, rather than waiting passively for the next crisis. (Rami Hikmat Fouad1 Mohammed Rawashdeh2, Adnan ALBashir2 &Bassam AL-Sharif, 2012)

Computerized Planning and Scheduling

Computerization of any management function has become possible and in some cases relatively Common. Computerization has yielded significant benefits, but it has also yielded disasters. Thus, if we are to be successful in computerizing maintenance management, it is necessary to know the components of the function. The components described here are appropriate for the various types or levels of maintenance work including routine, preventive, corrective, shutdown, facility, etc.

Work Order. A document that instructs the maintenance person in what is to be done. It identifies crafts, if appropriate; materials; special tools; critical times; and provides other necessary information to accomplish the job. If complete information is not provided, the document is a work request. A typical work order cycle using the CMMS software is presented in Figure 2.4

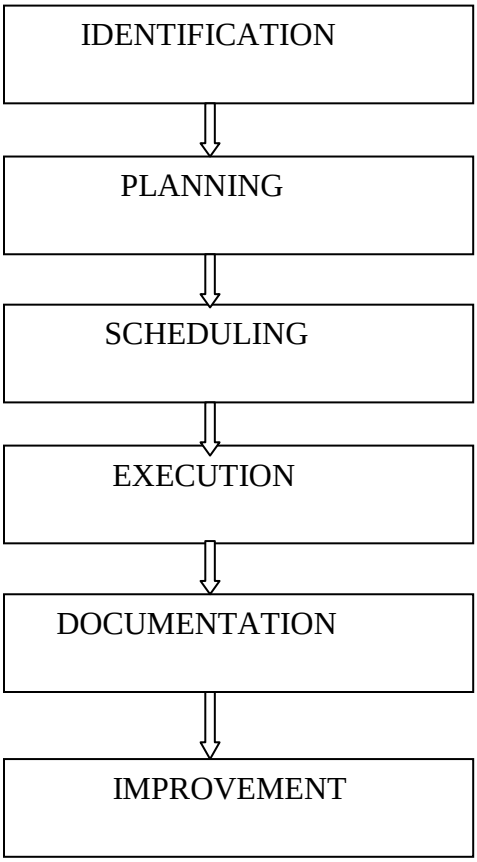

Figure 2.4 A typical work order cycle using the CMMS Software. ***Source: Rami Hikmat Fouad1 Mohammed Rawashdeh2, Adnan ALBashir2 &Bassam AL-Sharif, 2012***

Prioritizing. The act of determining which jobs have precedence. Since the function of maintenance has limited resources available at any given time, this act is always performed in a formal or informal manner.

Material Availability. A majority of the jobs performed by maintenance involve the use of materials. The material may range from a simple fastener to a sophisticated microprocessor and is necessary to provide the service that is requested.

Work Plan. The asking of why, what, who, where, when, and how the maintenance group will respond to a work request. It provides logical answers to these questions.

Job Sequence frequently called scheduling. It recognizes priorities and resource availability and can be done at several levels.

Backlog. A listing of work that is yet to be done.

Control Reports. An after-the-fact record, or accounting, or what has been done and some form of measurement. Computerization inherently means organization. In the case of maintenance management it means an organized database. The components of the maintenance management function determine what the elements of the database are included:

Assignment of Costs. This usually follows the patterns established by accounting procedures used at a particular facility. It generally recognizes cost centers, departments, divisions, etc., and frequently, but not necessarily, is geographically oriented. Although a variety of approaches can be used to develop sort levels or to accumulate costs, a clear definition of the approach is critical at the start of a program to computerize maintenance management.

Equipment Identification. This normally takes the form of equipment numbering and includes physical assets or functions on which maintenance resources will be expended. Careful consideration should be given here as to how finely equipment should be identified. For example, should each door in a facility be numbered or should all doors of a certain type be grouped together as one equipment? A case can be made for both approaches depending upon the type of facility and its needs.

Employee Lists. Those people who will be charging time to maintenance work have to be identified. In many cases this will involve the development of a trades or crafts list. In the case of multi craft facilities it may include the several levels within the maintenance multi craft category. Trades or crafts are then associated with employee lists for time and cost analysis. Employee lists should be reconcilable to payroll but not necessarily generate or drive payroll.

Priorities. The type of priority approach must be agreed upon when building the database for a computerized maintenance management system.

Work Orders. The format for the work order must be agreed upon at the beginning of the computerization.

Process. It is the key to accumulating and distributing cost, plus developing histories for future analysis. Although no database is preloaded, one is rapidly generated.

Parts Lists. In a complete maintenance planning and management control system, materials play an important role. Thus, a parts list or catalog for stocked material is necessary. These should be numbered, categorized, quantified, located, and priced when loading the database. In addition, provisions should be made for purchased parts that are not stocked. Depending on the sophistication and needs of the system, several other items are recommended when loading the database.

Cause Codes. Standardized identification of the basic causes of the work generated. This may be the basis for preventive maintenance programs or schedules that are part of the system. Cause codes provide a means for analyzing work and developing a corrective maintenance program.

Action Codes. Standardized identifications of what was done to respond to a work request. This is basically used to identify what level of "fix" was done and again can initiate a corrective maintenance program.

It should be noted here that a computerized maintenance management program does not, by itself, truly plan maintenance work. It cannot:

- Determine if the work request provides adequate information so that maintenance people understand what is to be done.
- Make a sketch to illustrate what is to be done.
- Decide what materials to use.
- Ascertain what time constraints exist because of production or other needs.

(Maintenance Engineering Hand Book Sixth Edition, Lindley R.Higgins R.Keith Mobley)

How to measure and increase maintenance productivity with CMMS Software

The ultimate goal of using a computerized maintenance management system is to increase productivity. Indeed, the investment of time, human resources, and financial considerations associated with implementing CMMS software is significant, so it's only reasonable to expect. The objectives of CMMS is to improve maintenance costs, reduced device's downtime as a result of scheduled preventative maintenance, increased device's life, ability to store historical records

to assist in the planning and budgeting of maintenance and ability to generate maintenance reports returns in the form of increased efficiency.

To a certain degree, the mechanics of measuring and reporting maintenance productivity will vary from system to system, in that the process of creating and running reports will differ. However, there are certain broad-based approaches to measuring and increasing maintenance productivity that will prove valuable, regardless of the computerized maintenance management system selected.

The first key is to remember that every software package is only as good as the data that is entered into it. This seems obvious, but reports cannot be run off of data points that are not captured. Therefore, it is important to gather all data points possible. In relation to the assets themselves, data points to capture include:

- ✓ Serial number;
- ✓ Model numbers;
- ✓ Manufacturer;
- ✓ Warranty details; and
- ✓ Purchase dates.

However, it is not only assets that can be tracked. Invaluable information can also be gathered regarding your maintenance technicians' performance. By ensuring that each maintenance task is properly recorded and catalogued in the CMMS system and then implementing a carefully chosen set of key performance indicators (KPIs) based on that data, managers can evaluate the effectiveness and productivity of technicians. KPIs enable managers to measure the efficiency of a department and identify areas for improvement. Benchmarking, or in other words, comparing past performance to current performance or comparing department performance to that of other departments, can help managers improve productivity. (Lindley R.Higgins R.Keith Mobley,2002)

2.9 Top Computerized Maintenance Management Systems (CMMS) Products

- **eMaint CMMS**

eMaint X3 is an affordable, flexible and user-friendly management system that offers asset and inventory control, condition monitoring and scheduling tools. Mobile-friendly, it features customizable reporting and dashboard tools.

- **Maintenance Connection**

A powerful web-based system, Maintenance Connection features multi-site asset tracking, contract and project management and preventative maintenance. Scale able and seamlessly integrates with other software.

- **FTMaintenance**

FTMaintenance, by FasTrak, is a maintenance management software platform that automates daily tasks related to work orders, asset and equipment management, MRO inventory, preventive maintenance and predictive maintenance.

- **Facilities Management eXpress**

FMX is a Web-based computerized maintenance management software system that supports QR code tracking and drag-and-drop mobile calendars. Supports unlimited users and unlimited number of tracked assets.

- **Hippo CMMS**

Offering one of the most robust CMMS solutions on the market, HippoFM combines its intuitive graphical interface with powerful reporting tools and mobile technology to efficiently streamline your maintenance management operations.

- **Maintenance Edge by Dude Solutions**

Dude Solutions provides a suite of web-based maintenance management applications that help businesses to streamline maintenance operations with centralized requests, automated maintenance workflow, and simple reporting.

- **Fiix**

Fiix is a cloud-based maintenance management solution that helps users manage day-to-day work orders and work towards establishing preventive maintenance strategies.

- **MPulse**

Whether you're a small maintenance shop or large organization, MPulse has the CMMS system to fit your needs. Choose from four customizable software editions that feature work order management, tracking, scheduling and reporting.

- **MAPCON**

Designed specifically for companies in the manufacturing and facilities industries, MAPCON is a maintenance management system that offers standalone asset management, preventive maintenance, work order management, and more.

- **Megamation Direct Line**

With over 25 years in the facilities and maintenance management space, Direct Line by Megamation has over 26 full-featured modules to empower businesses to create a custom-fit system to meet their unique needs.

- **IBM Maximo**

Maximo Asset Management by IBM combines asset management with maintenance management. From a single system, companies can monitor and manage the full life cycle of their enterprise assets, including facilities, communications, and transportation.

- **TabWare by AssetPoint**

TabWare is a full-featured CMMS/EAM solution made exclusively for maintenance managers.The solution contains advanced analytics that make use of the data created stored during day-to-day operations so that companies can gain full visibility.

- **ManagerPlus**: Manager Plus is a CMMS solution that helps growing organizations manage their assets, maintenance, inventory, and purchasing. ManagerPlus is fit for asset-intensive industries like agriculture, construction, transportation and manufacturing.
- **Agility by SoftSols Group**

Agility, created by SoftSols Group, is a CMMS/CAFM system for maintenance and facility managers to use on-site and in the field. The solution offers a full suite of applications, including asset management, reactive and preventive management.

- **MicroMain Maintenance Software**

  An easy-to-use CMMS system, MicroMain helps businesses simplify and streamline every step of their maintenance operations. Features preventative maintenance, purchase order automation and supplier and vendor tracking.

- **UpKeep**

UpKeep is web-based computerized maintenance management software (CMMS) and enterprise asset management (EAM) solution with a focus on mobile use. The system is accessible on desktops, laptops, tablets and smart phones.

- **WebDPW**

WebDPW™ by BMSI (Business Management Systems Inc.) is a complete maintenance management solution for organizations seeking a way to automate their service process. With WebDPW, users can quickly manage technicians and generate work.

- **IFS Applications**

Designed specifically for to-order manufacturers and asset-intensive companies around the globe, IFS Applications is relied upon by its large global customer base by supporting intricate order-driven and mixed-mode manufacturing requirements.

- **HCSS Equipment 360**

HCSS Equipment 360 is a maintenance management solution for businesses of all sizes. It's tailored for the Construction industry, but also suits the needs of the oil/gas, field maintenance, and utilities verticals.

- **MP**

Manage equipment and facilities, schedules, reports, unlimited work orders and control spare parts inventory. (http://www.softwareadvice.com/cmms/#top-products)

CHAPTER THREE

Research Methodology and Data Collection

In this study both primary and secondary information source was used. Primary source contained raw, original, non-interpreted and unevaluated information. The secondary data sources were technical documents, annual reports ,books, journals, senior thesis work, manuals, available documents, organizational chart, brochures, company manuals, and electronic retrievals that help to cross check the official information and to get details concerning the study. Discussion, interview and questionnaires were techniques that were used for gathering primary information and relevant data for the study.

3.1 Methods of data collection

Data collection is in both qualitative and quantitative nature. The data required for the study was identified and collected by communicating maintenance staff of Army Foundation Adama Garment Industry. A focused discussion and interviews were held with the respective maintenance personnel of the industry by visiting them frequently. Questionnaire was prepared and given for maintenance department of the industry to have information, which can expressed the total maintenance activities within the industry. Having the result collected, the culture and the system of maintenance in Army Foundation Adama Garment Industry had studied and pointed out. Further analysis of maintenance activities including maintenance and other equipment downtime based on the existing maintenance systems of the industry also studied.

After analyzing the current situation of maintenance department, the optimized methods or approach of maintenance were selected.

3.1.1 Sample design

The population count of production equipment in Army Foundation Adama Garment Industry was 669. Analyzing every machine is difficult because of cost and time constraint. In garment production the machinery arrangement is straight (one machine output is input for next machine).A constrain machine (low productive) affects the hole downstream process performance, so the most bottleneck machinery in the line were selected using non-probability sample method which is purposive (Judgmental) sampling technique . Based on judgment of the

technique department and engineering team collaborate with production department. Sample sizes of 17 bottleneck machineries selected for study from three factories i.e. seven from garment factory, five from Canvas and Leather product factory and five from Weaving and Embroidery product factory.

In addition, Sample of 21 respondents were selected (2 respondents from top management, 3 respondents from supervisors, 3 from production managers and 13 respondents from maintenance department).

3.1.2 The Case study process

There are three factories in the industry each containing three main workstation (Cutting, stitching, and finishing). The Study planned to conduct one month maintenance report of the industry (February 2017) .According to Mss. Yaineabeba Mohammodnur (2016) who did research on the equipment performance of same industry, appropriate improvement in performance and productivity could be successful if the following steps are followed:

The first step of this work is providing on the job training for critical department staff (operators, supervisors and maintenance personnel) on how to measure and record observation data.

The second step is identifying the bottleneck machines that require immediate attention in a manufacturing plant where production processes are conducted. Selection of machines that carried out using purposive sampling technique based on equipment. Production, technique and quality department experts were allowed to select the most bottleneck machines (frequently fail) from production area of each factory.

The third step identified the down time that occurred in the manufacturing plant due to breakdown. The identification process was carried out by analyzing the observation data record from each bottleneck machine in the factories.

Final step were summarizing machine downtime by performing a root cause analysis. Losses due to down time of equipment-specific (failures, problems, or breakdowns).These types of summarizing of causes enable easy analysis and identification of problem area. (Yaineabeba Mohammodnur, The study of capacity and performance using overall equipment effectiveness, (2016)

3.2 Data Collection

In this section the data and information collected from Army Foundation Adama Garment Industry is presented and analyzed. After over viewing the industry, the maintenance section is selected to take the necessary data and analyze the problem in detail. Data and information contains interims of the current status of the industry, location and capacity of the industry, available machine tools and other facilities in the production workshops, bottleneck machines, downtimes, and etc. The survey questionnaire contains 17 questions. These were distributed to 21 Adama Garment Industry staffs', which are representative employees of each department shown in Table 3-1 below. Out of the 21 questionnaires, 18 were filled and returned. This means 85.7% respondent rate.

Table 3-1: Summary of data distributed & returned

Data Collection			
Name of departments	No of Questionnaires Circulated	No of Questionnaires Returned	Respondent Rate
Top managers	2	2	2/2=100%
Supervisors	3	2	2/3=66.6%
Production managers	3	3	3/3=100%
Maintenance workers	13	11	11/13=84.6%
Total	21	18	18/21=85.7%

3.2.1 Current Status of the Industry Organizational Structure of the Maintenance Department

Currently the maintenance department is organized by having three main divisions. The maintenance head is directly accountable to the general manager. The organizational structure of the maintenance department follows the method of organizing by shop. Each shop has a manager responsible for all activities done by the workforce under him. Under these managers there are supervisors, who lead the actual work accomplished in the industry. The groups, directed by these supervisors, are well staffed starting from senior to junior of the profession required. The way the organization structured, organizing by shop, has an advantage in specialization of the work done in the shop and also it is easy to assign the right skilled manpower. However, the

structure by itself lacks machine familiarity by the craft men, which highly affect the speed of maintenance accomplishment. To avoid this, the industry separates the mechanics and electricians in two groups for all work section.

3.2.2 Workshop Facility and Capacity

All of the three division of the maintenance department have their own shop, equipped with different machines. The machines are tried to be arranged in process layout. But the location of each machines in the shops are not comfortable for the workers.

3.2.3 Maintenance Planning and Controlling System

There is a section, in AGI called 'Design, maintenance planning and controlling section', under maintenance department. But the controlling mechanism of the maintenance department is not also well established. The supervisors, who make the job, control their own work. This may seems good that the maintenance supervisor feels more responsibility on his job. But with the existing situation, this mechanism makes work not to be done correctly, which becomes a cause for frequent breakdown of machines.

3.2.4 Work Flow of Maintenance

In Adama Garment Industry the maintenance activities are performed in one way; when machine is breakdown that is corrective maintenance and there is no scheduled maintenance plan (preventive maintenance plan). When breakdown occurs the production department informs the maintenance department by requisition paper. After receiving the request, the maintenance manager passes the work to the concerned division regarded to the compliant, if necessary craftsman are assigned to justify the problem. Finally, it reaches to the craftsman through supervisor. The accomplished work is approved by supervisors and then reported to managers. The existing workflow of the maintenance department of this industry is shown in Figure3.1.

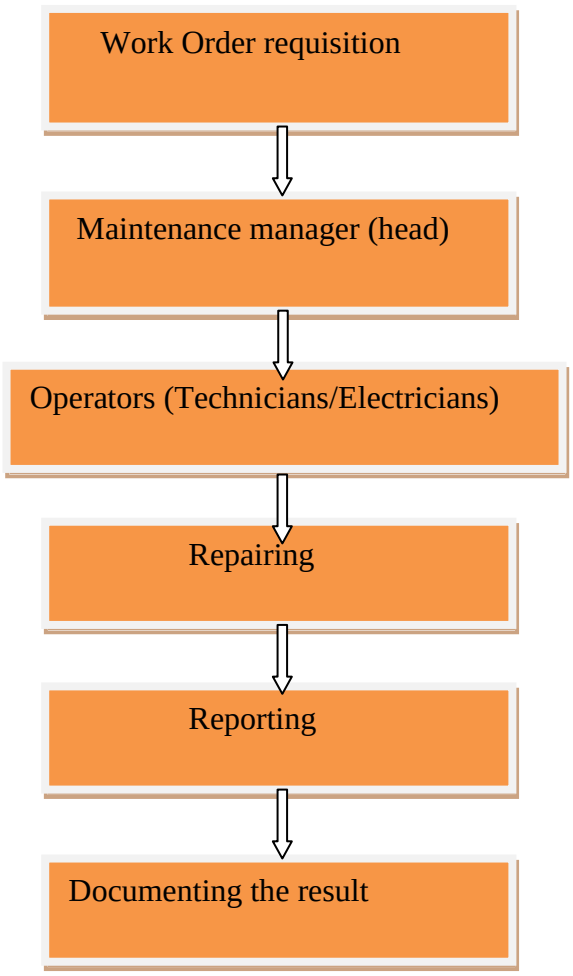

Figure 3.1 The existing flow of the maintenance department.

The table 3.2 is the summery of the questionnaires distributed to the AFAGI and my own observation, with the following grade. The respondents (21 members) were top managements, supervisors, production managers and maintenance workers. The questioner, which is distributed to this industry, is attached in the Appendix 2

Table 3-2 The summery of the questionnaires distributed to AFAGI.

No.	Questionnaire	Alternatives	Frequency	Percent (%)
1	Is there a scheduled program for effective maintenance management in your industry?	Yes	5	23.8
		No	16	76.2
	Total		21	100
2	Is any maintenance works are recorded?	Yes	7	33.3
		No	14	66.7
	Total		21	100
3	Is there preventive maintenance done for machines before problem occur?	Yes	5	23.8
		No	16	76.2
	Total		21	100
4	Is there coordination between the production and maintenance department?	Yes	7	33.3
		No	13	61.9
	Total		20	95.2
5	Did proper tools and instruments are brought at the right time?	Yes	5	23.8
		No	16	76.2
	Total		21	100
6	Is maintenance the responsibility of every worker in the company?	Yes	6	28.6
		No	15	71.4
	Total		21	100
7	Are operator's checks and clean equipment before and after work?	Yes	7	33.3
		No	14	66.7
	Total		21	100
8	Does further training is given for maintenance workers, supervisors, planner/scheduler, quality and productivity control to update their skill with new technology system?	Yes	5	23.8
		No	1 6	76.2
	Total		21	100
9	Job descriptions are available for all maintenance positions and supervisors?	Yes	9	42.8
		No	12	57.2
	Total		21	100
10	Is there maintenance tools/equipments quality and quantity?	Yes	8	38.1
		No	13	61.9
	Total		21	100
11	Is there perfect quality and skill level of supervisors group?	Yes	7	33.3
		No	14	66.7
	Total		21	100
12	Is the industry uses work order properly?	Yes	6	28.6
		No	13	61.9
	Total		19	90.5
13	Does the top managements have understanding for	Yes	5	23.8

	preventive and predictive maintenance?	No	16	76.2
	Total		21	100
14	Does the supervisors and maintenance workers have understanding about CMMS (Computerized maintenance Management System)?	Yes	4	19
		No	17	81
	Total		21	100
15	Is there a discussion between the managers and the production workers about the production process?	Yes	6	28.6
		No	15	71.4
	Total		21	100
16	Did the industry motivates the workers to be more productive?	Yes	5	23.8
		No	16	76.2
	Total		21	100
17	Is there perfect maintenance work shop area location in the industry?	Yes	7	33.3
		No	14	66.7
	Total		21	100

CHAPTER FOUR

Data Presentation and Analysis

4.1 Analyzing Current Situation of Army Foundation Adama Garment Industry

The current situation of the industry is analyzed based on the previous chapter. The following points are seen to be the major problems of this industry.

- The maintenance departments of the industry do not use Preventive Maintenance (PM) totally. The industry usually practices corrective maintenance (CM) in its operating system. This process is a reactive maintenance approach, and resulted extended and unplanned downtime during operation. Such kind of maintenance system practiced by the maintenance department is not advisable.
- The maintenance department of the industry do not use work order properly or do not use this system totally. It is one of the most indicators of the status of a maintenance department. If a maintenance organization does not have a work order system, it is impossible to measure or control maintenance activity.
- The maintenance department of the industry, almost not perform any failure analysis from the feedback of machine breakdown. For an operation to be cost effective, good practice in failure analysis must be followed.
- It is known that preventive maintenance is another major part of any successful maintenance program to be productive. AFAGI do not use preventive maintenance program properly. Without successful preventive maintenance program, maintenance can only react to given situation. Preventive maintenance allows the organization to plan better and reduce maintenance cost.
- One of the most important operations concerning preventive maintenance is lubrication. Lubrication reduces friction to increase the life of parts which have relative motions between them. While this is the fact in most cases the maintenance department do not uses the lubrication program properly.
- The other fact related to the preventive maintenance is the lack of coordination between the production and maintenance. In this industry, maintenance department given less attention than other department. But preventive maintenance should be an organizational

policy. On the other hand, in this industry, the problem is communication. Good communication must be established to make preventive maintenance effective.

- Material management, what type of spare parts and how much should be stocked, is also the main problem for this industry. Therefore the minimum order level is not known and so the machines downtime increases due to lack of spare parts.
- The biggest problem in this industry is data recording and documentation. Most of time they don't know what to record and so they document insufficient data that may not be used as a feedback or for the maintenance analysis. Therefore the significance of maintenance department cannot be seen or analyzed. They do not know exactly how high the maintenance cost is.
- Lack of proper tools and instruments for repair and diagnosis of failure is also the other cause for most maintenance delay. Proper tools and instruments should be available for quick response of maintenance department and to decrease the down time of machines.
- Training for maintenance personnel is very essential to improve the skills of the labor force. If equipment complexity increases faster than the technical capability of craftsmen, the gap will cause a decline in productivity.
- The other problem of the industry is most of the time operators are do not checks and clean equipments before and after work so because of this reason the life time of equipments easily decreases.
- The other problem of the industry is Supervisors and maintenance department workers have no well understanding about Computerized Maintenance Management System (CMMS). But implementing CMMS is important tool for the industry to improve productivity and to minimize machine down time.
- These are the major problems associated with the maintenance activities of Army Foundation Adama Garment Industry. As can be seen from the above points, the industry faces a big problem on maintenance area. Therefore the maintenance department should be reorganized to minimize the above problems. The recommended system will be presented in the next chapter.

4.2 Available machine tools and other facilities in the production workshops

This data is helps to develop or plan preventive maintenance schedule by using CMMS (Computerized Maintenance Management System). (Appendex 3)

4.3 Quantitative Data

The data, presented below, helps to calculate the amount of the maintenance cost. Thus the selected necessary data are:

4.3.1 Total Cost of Production in Army Foundation Adama Garment Industry.

To produce different products there are costs associated with it. The common production costs for garment industry are raw material cost, labor cost, overhead cost. And the operating expenses are general & administration cost and selling & distributing costs. The amount of total cost of each type for 2008/16 is taken from the annual report of the industry and shown as follow.

Table 4.1 Total Cost of Production in AFAGI

Type of cost	Cost in birr
Production cost	104,382,343.00
Operating expense	8,131,067.00
Maintenance cost	462,079.00
Total cost	112,975,489.00

4.3.2 Maintenance cost analysis

The common production costs of garment are raw material cost, chemical cost, labor cost and Overhead cost. From the Table 4.1 the production cost is about 90% of the total cost of the industry. The operating cost that is the administration, selling and distribution costs are the second larger cost, 7.2 % of the total cost. Maintenance cost is the least of the total cost that is 0.4 % of the total cost. However the hidden cost that comes from lack of proper maintenance is too big. From this data, maintenance cost data is not correct data because the cost of maintaining equipment often varies from 2 to 20 % of the total cost. But in this maintenance cost data employee wage, spare parts cost, over time cost, non functional machines (Appendix 3-D) due to spare pats cost and other costs are not included so this indicates in this industry a big problem is data recording and documentation. That is, the loss of production due to the unavailability of the machines and the cost associated with this downtime are large.

4.4 Bottleneck Machines and their Production capacity in AFAGI.

The machines data selected based on the most bottleneck machines (frequently fail) from production area of each factory (Table 4.2).

Table 4.2 Bottleneck Machines and their Production capacity in AFAGI.

No	Machine name	Machine model	Production capacity/day
1	Button hole machine	LBH-17905	362
2	Packing machine	C-03	362
3	Cutting machine	KSAuv	800
4	Brother single machine	DB2-BT55	362
5	Pegasus machine	L52-01	724
6	Turkey weaving machine	LDMEK ESME	500
7	Weaving machine	OMM-01	840
8	Sewing machine	SF type	240
9	Mitsubishi single needle	LU2-490	240
10	Single needle Mitsubishi	LU2-400	240
11	Mitsubishi single needle	LU2-400	240
12	Sun star single needle machine	KM-560	600
13	Juki single needle	DDL8300N	290
14	Zoje double needle machine	0705010001	150
15	Zoje single needle machine	ZJ928-P1	150
16	Gemsy over lock	GEM7375	100
17	Typical machine	GC5550	200

4.5 Data on machine down time.

The bottle neck machines with their time they spend due to breakdown in February 2009/17 is listed below in Table 4.3, which helps to analyze the causes of machine down time and to prepare preventive maintenance plan for the industry.

Table 4.3 Data on machine down time and their root cause in February 2009/17

No	Machine name	Total down time/hr and Min	Root Cause	Action taken
1	Buttonhole machine	15hrs 30 min	-The tension controller is too tight -Blade point of sawing hook has scratches -The needle is broken	-Adjust or decrease the tension of tension controller -Replace the sawing hook -Replace new needle
2	Packing machine	12hr	-Roister and wire not working.	-Adjust the roister and changing the new wire
3	Cutting machine	10hr	-Cutter broken and switch problem	-Change new cutter and switch
4	Brother single machine	12hrs10 min	- Switch button problem - The machine does not lubricant	-Fill the oil before starting the machine
5	Pegasus machine	6hr	-Plate problem -Needle broken	-Adjust the plate in correct position -Change the new needle
6	Turkey weaving machine	8hr	- Needle holder and -wrapper problem.	-Change needle holder and -Adjust wrapper problem
7	Weaving machine	17hrs20 min	-Spring, harness, and -needle broken	-Adjust spring, harness weft -Change new needle
8	Sewing machine	10hr	-Tension post controller problem	-Adjust the tension post controller

			-needle broken.	-Change new needle
9	Mitsubishi single needle	10hr	- Poor timing of the sewing hook -The bobbin thread tension is too high	-Readjust the sewing hooks timing by the timing gauge
10	Single needle Mitsubishi	15hr25min	-Poor timing of the sewing hook -Tension controller is too tight ,The belt shifter of the speed transmitter has not changed to the high speed pulley	-Readjust the sewing hooks timing by the timing gauge -Decreasing the tension controller -Lubricate the shifter driving pin.
11	Mitsubishi single needle	20hr	-Switch and phase drop not function - Barker damming problem	-Adjust Switch and phase drop -Change barker
12	Sun star single needle machine	13hr	-Motor output connector problem -Clutch is not function	-Check the motor output connector for loose connector and disconnect.
13	Juki single needle	10hr	-The needle is bent -The needle and hook blades touch with each other -The needle is broken	-Replace the needle -Readjust the position of the needle and the sewing hook
14	Zoje double needle machine	25hr	-The tension of tension controller is too tighten, -The tension or the stroke of a take up spring is to great -Timing problem	-Decrease the tension of tension controller -Decrease the tension or the stroke of the take up spring.
15	Zoje single	12hr40min	-Upper and lower lopper not	-Adjusting upper and lower

	needle machine		working -Oil level in the oil reservoir is too low	lopper -Fill the lubrication oil up to high mark
16	Gemsy over lock	12hr	-Upper and lower lopper, motor problem, timing problem and plate not function	-Adjust upper and lower lopper - Timing for dropping the knife
17	Typical machine	14hr	-The needle thread trimmer is interfered by the work clamp check or the trimmer driving plate. -Timing problem	-Readjust the installation of the trimmer or the position of the trimmer driving plate -Adjusting the time for dropping

These machines are critical machines that control the overall production flow of all the problems that occur, they can all be generally classified as problems that occur mainly due to breakdown and other electrical or technical problems. Breakdowns are the root of all problems, because when they occur, production stops, deliveries are delayed, and production defects are created; in other word a single breakdown can affect the whole processes. That is why the preventive maintenance system is a core of any maintenance operation. Therefore applying preventive maintenance plan or scheduling is necessary for AFAGI.

It is the universal truth that damaged equipment signaled its abnormality through unusual vibrations, noises or other symptom. If the workers had read these signs and responded accordingly, the breakdown could have been avoided. Thus the human factor is the root cause of the breakdown.

4.6 Effective Maintenance Scheduling By Using CMMS Program

The current maintenance management system of Army Foundation Adama Garment Industry is seen previously. But, if the system is automated, it will be more efficient. Productivity of maintenance department can be improved through this CMMS program. Because the plan becomes effective if it gets sufficient feedback forms the previous analyzed maintenance

activities. This is the problem of AFAG industry, as it is explained in the introduction section. Moreover the program helps the AFAG industry to evaluate employees in the maintenance department. In general, they will be much benefited, especially in recording and documenting the necessary information, if they install it.

This sub-section has the content of the developed program specifically for this industry. The program has eleven entity menus (catalog). It is user friendly and if any difficulty the help menu gives how to use the program. Below, each of these entity menus is discussed in brief.

The entity menus are equipment catalog, location catalog, routine maintenance catalog, non routine maintenance catalog, predictive maintenance catalog, resources menu catalog, readings control catalog, work orders ,vouchers and consumptions catalog, calendars catalog, information analysis catalog, warranties and documents. Thus all entities the help menu gives how to use the program.

For this study to show an example of maintenance plan by using CMMS, only two entity menus are selected these are Equipment catalog menu and Routine maintenance catalog menu.

- Maintenance plan for selected machineries is shown in Appendix 4.

4.6.1 Equipment Catalog Menu

The equipment catalog menu contains all the necessary data concerning the machine in the company. Here, the type, product, capacity, brand, model, id, serial no, plate, and other information of the machine will be recorded. This helps to know the details about the machine whenever needed. Moreover, the preventive maintenance program for the machine can be easily accessed using this menu. Every preventive maintenance actions that should be taken are included and can be modified anytime by the planner. Search bar by machine number is available for ease of retrieval. Once the equipments are registered, the MP allows documenting and updating our information.

The figure below shows the interface of the equipments catalogue menu of the program.

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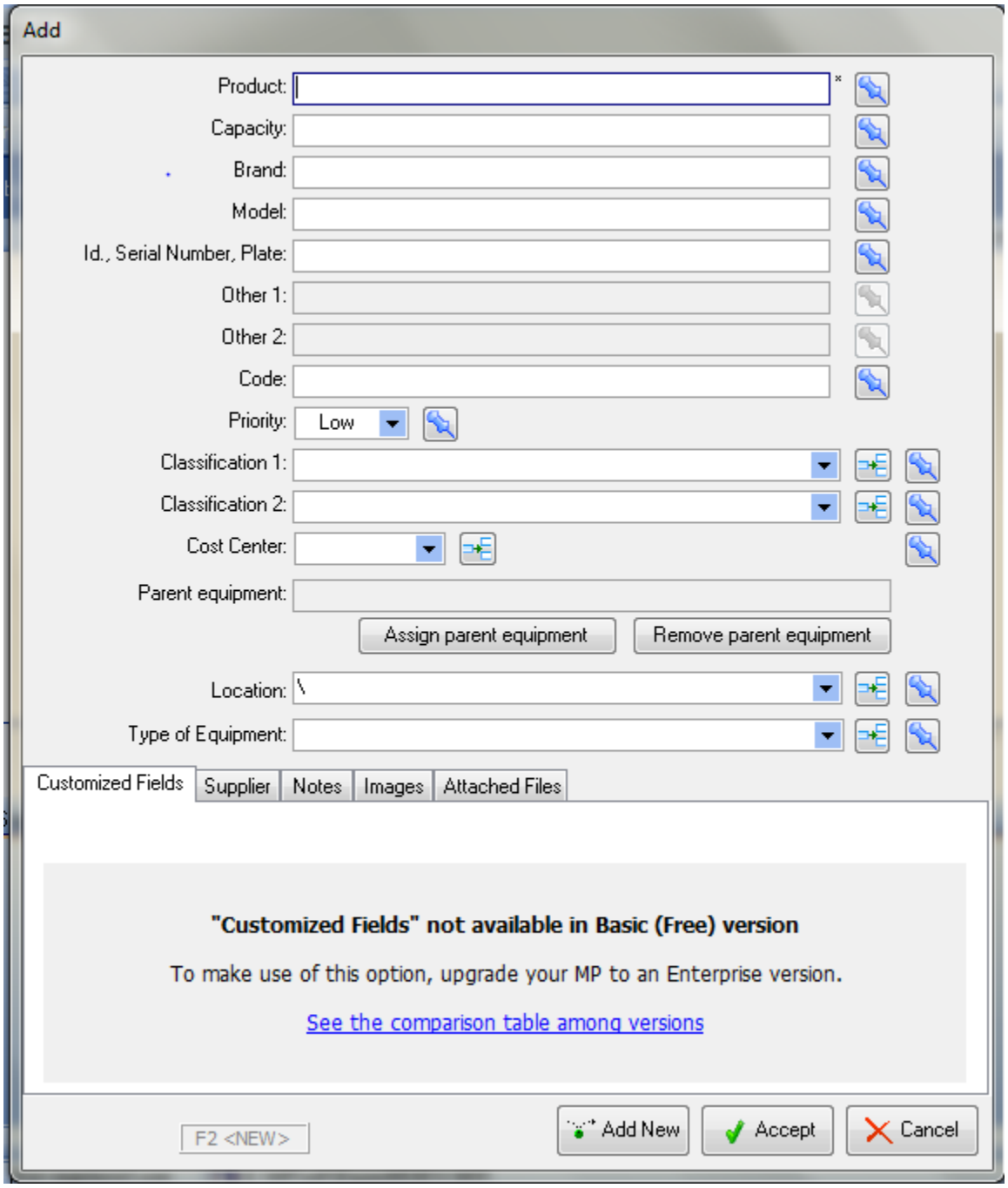

Figure 4.1 The equipment catalog menu of the program

4.6.2 Routine Maintenance Catalog Menu

This menu helps to register the parts, activities, and frequencies of the maintenance plan. A maintenance plan is the group of Routine Maintenance activities to be performed on equipment. Routine maintenance activities are generally actions focus on preventing failures and are performed on a cyclical and recurrent basis with a specific frequency. The figure below shows the interface of the routine maintenance plan menu of the program.

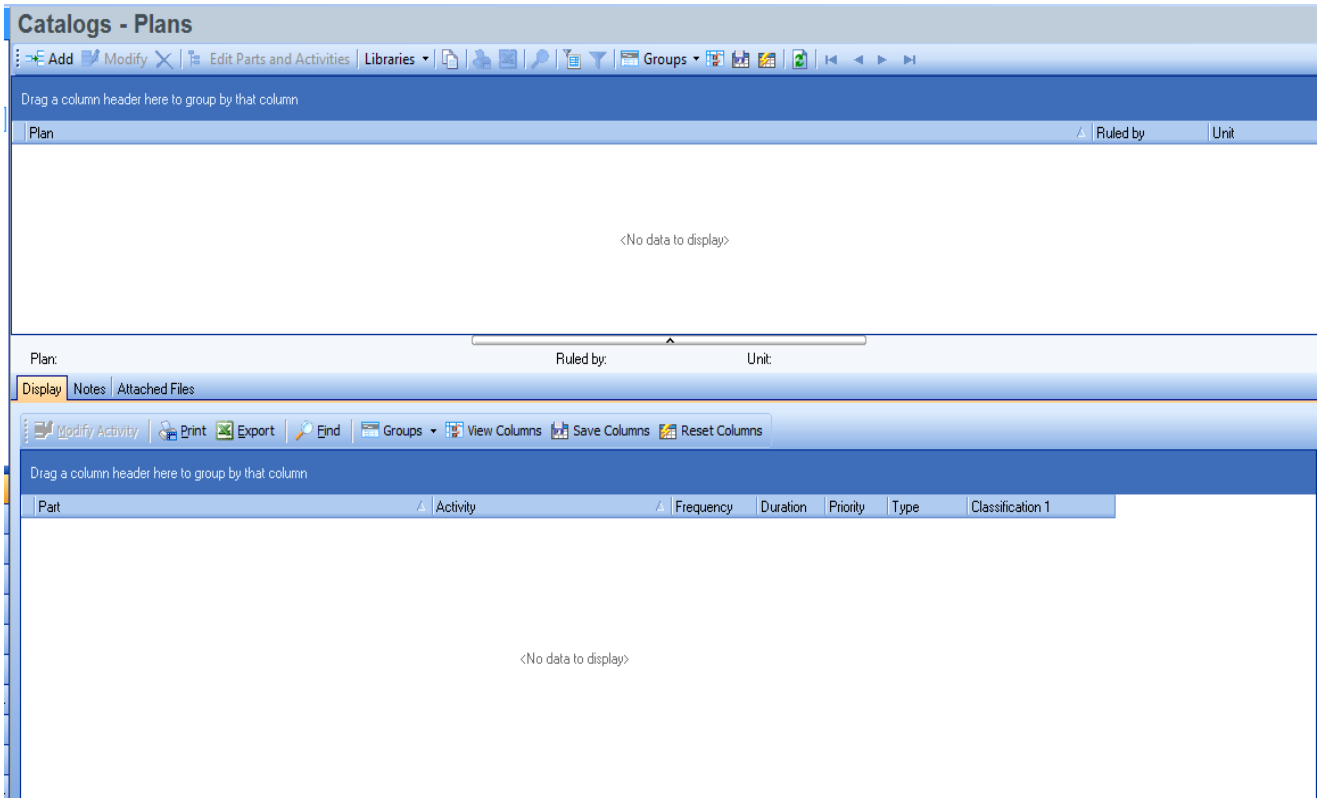

Figure 4.2 The routine maintenance plan menu of the program.

CHAPTER FIVE

Findings, Conclusions and Recommendations

5.1 Main findings of the study

- Lack of coordination between production and maintenance.
- Lack of training for maintenance personnel.
- Data recording and documentation problem.
- Lack of proper tools and instruments.
- Lack of well understanding about Computerized Maintenance Management System (CMMS).

5.2 Conclusions

Based on the findings in the previous sections, equipment maintenance system of this industry (Army Foundation Adama Garment Industry) needs much improvement. Maintenance department of this industry should be well equipped with resources to assure the cost effective availability of machines to increase productivity. As it is seen in chapter 2, maintenance has a great impact on the productivity improvement; but it has received little notice in this industry.

In this paper AFAGI is taken as source and reference for the case study. It is seen that most of the work order, in this industry, is generated from breakdown of machines. This shows most of the maintenance activities are corrective action rather than preventive. In effect, the downtime of the machines rises.

As it is the main objective, this paper proposed a model for the scheduling of maintenance management system, considering the existing problem. The implementation of the CMMS (Computerized Maintenance Management System) software helps the maintenance department to move from conducting corrective maintenance to preventive maintenance which not only keeps the organization running more smoothly, but also impact on the safety and quality of life in the organization. The use of preventive maintenance also extends the life span of the equipment. So the productivity will be improved.

Generally maintenance planning section has a great role in the model developed. It is the responsibility of this section to coordinate the corrective and preventive maintenance with the limited resources, and set the maintenance program considering the factors and the feedback of maintenance report.

5.3 Recommendations

The following recommendations are proposed for Army Foundation Adama Garment Industry based on the outcome of the paper.

- Maintenance should be an organizational policy as one of the strategy in being productive and competitive. And the maintenance department should be given attention, as it is one of the main areas for productivity improvement.
- Maintenance awareness and commitment should be created in the industry starting from the top management up to the lower level through training.
- Industry should encourage the operators to become familiar with the machines they operate and to know about the CMMS (computerized maintenance management system).
- Equipment operator should be responsible for machine and the workplace by taking every breakdown as his problem. Taking responsibility means taking action.
- The equipments should be kept so clean because most of the problems develop from dirty machines and also cleaning is one of the best ways to check for abnormalities and dealing with them at the early stage.
- Daily, weekly, and monthly checklist should be available for every machine to be inspected by operators, mechanics and electricians. The frequency of inspection should consider the equipment history as well as factors like status of the equipment.
- Finally, any preventive maintenance activities should be given emphasis, as it is the best solution to increase the life of equipment. Thus maintenance and production has to be integrated with a common goal of the industries to alleviate the conflict created between them. Here, the maintenance plan should consider the production plan whenever planned. The production department staffs also should understand about and preventive maintenance activities and should provide the equipment whenever needed. Also operators should understand about computerized maintenance management system

(CMMS) and apply this system in all maintenance activities to improve productivity of the industry

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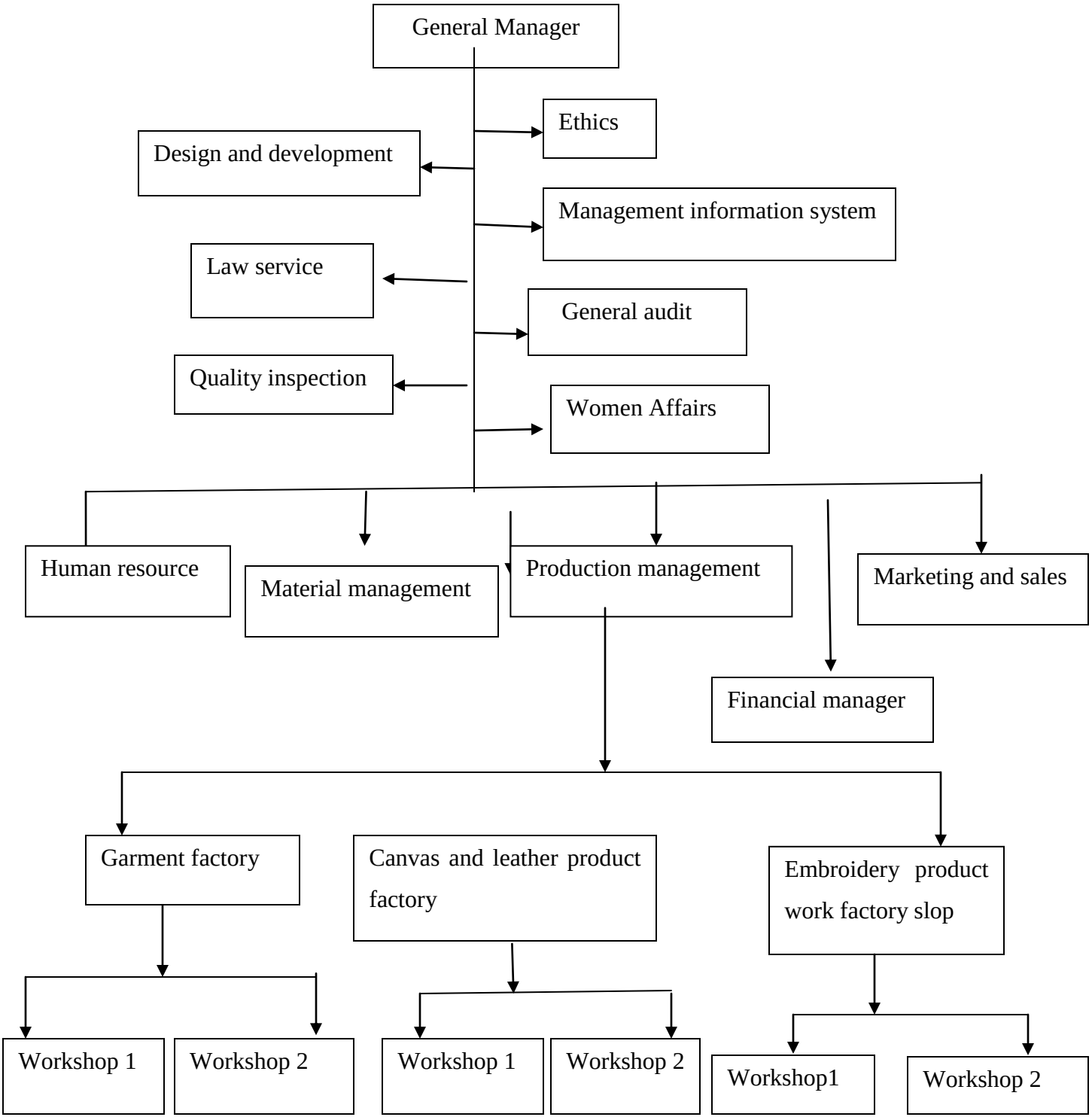
Appendices

Appendix 1 Organizational structure of the industry (AFAGI)



Appendix 2 Questionnaire for Survey

Adama Science and Technology University Department of Manufacturing Engineering.

The questioner, which is distributed to Army Foundation Adama Garment Industry to know where the maintenance department stands, is prepared for maintenance personals especially for supervisors or managers.

No	Questionnaire	Alternatives	
1	Is there a scheduled program for effective maintenance management in your industry?	Yes	No
2	Is any maintenance works are recorded?	Yes	No
3	Is there preventive maintenance done for machines before problem occur?	Yes	No
4	Is there coordination between the production and maintenance department?	Yes	No
5	Did proper tools and instruments are brought at the right time?	Yes	No
6	Is maintenance the responsibility of every worker in the company?	Yes	No
7	Are operator's checks and clean equipment before and after work?	Yes	No
8	Does further training is given for maintenance workers, supervisors, planner/scheduler, quality and productivity control to update their skill with new technology system?	Yes	No
9	Job descriptions are available for all maintenance positions and supervisors?	Yes	No
10	Is there maintenance tools/equipments quality and quantity?	Yes	No
11	Is there perfect quality and skill level of supervisors group?	Yes	No
12	Is the industry uses work order properly?	Yes	No
13	Does the top managements have understanding for preventive and predictive maintenance?	Yes	No
14	Does the supervisors and maintenance workers have understanding about CMMS (Computerized maintenance Management System)?	Yes	No

15	Is there a discussion between the managers and the production workers about the production process?	Yes	No
16	Did the industry motivate the workers to be more productive?	Yes	No
17	Is there perfect maintenance work shop area location in the industry?	Yes	No

Appendix 3 List of machine tools in AFAGI

A- Available machine tools in garment factory

No.	Model	Factory S/ No	Foundation S/N	Type of machine	Qty.	Purchased date
1	GC5550	06053633	157-05-7311-22-01-0107	Typical single needle	30	2000
2	DDL8300N	4DOYH0912	157-05-7311-22-01-0108	Juki single needle	18	2000
3	Z5970 IRD3/PF	110601229	157-05-7311-22-01-0085	Zoje single needle	14	2000
4	JK 8709pf	060805520	157-05-7311-22-01-0012	Jack single needle	2	2006
5	ZJ970IR503	110501159	157-05-7311-22-01-0129	Single Nideele zoje	7	1999
6	LBH-17905	2IF0034	157-05-7311-22-01-0040	Button hole juki	16	2006
7	GEM 757t-XH	5102170003	157-05-1731-22-01-0023	Gemesy over look	3	2006
8	LH-3128	313ydo153	157-05-1731-22-01-0136	Juki double needle	10	2003
9	516m2-55	24007251	157-05-1731-22-02-0030	Siruba linter look	10	1994
10	JK8700	60805518	157-05-1731-22-01-0013	Button attach juki	13	2006
11	LK1900-HS	2L1CJ00475	157-05-1731-22-01-0150	Partacker juki	15	1999
12	LK900A-HS	2LIEH02829	-	Juki BARTAKER	3	2006
13	261ms	-	157-05-1731-22-02-0015	Juki ms single N	2	2006
14	L52-01	8334306	157-05-1731-22-02-0022	Pegases /over look/	14	1999
15	GEM 1108	10100400	157-05-1731-22-02-0261	Gemesy button attach	3	1998
16	Stp 15	-	157-05-1731-06-02-0001	Case ironing m/c	5	1999
17	STP 14	-	157-05-1731-06-01-0002	Colar ironing mc	2	1999

B- Available machine tools in Canvas and leather product factory

	Model	Factory S/N	Foundation S/N	Type of machine	Qty	Purchased date
1	Lu2-400	771650	157-06-17311-22-01-0003	Mitsubishi single needle	65	1987
2	Km-560	81105256	157-06-17311-22-01-0024	Sun star single needle	14	2002
3	GC 550	0803587	157-06-17311-22-01-0024	Typical single needle	4	1987
4	Zj 9701R-Sa3/pf	10501245	157-06-17311-22-01-0034	Zoje single needle	26	2006
5	Zj 0302 cx	11061228	157-06-17311-22-01-0129	Zoje single needle	13	2006
6	Kn-560	81105262	157-06-17311-22-01-0120	Brother single needle	3	2006
7	DB2 –BT55	M89105713	157-06-17311-22-01-0025	Brother single needle	2	2006
8	GEM 7375	5072010030	157-10-17311-22-02-0001	Gemsy over lock	1	1998
9	Lk3-B434-t43	G95188998	157-06-17311-22-02-0003	Brother bar tucker	30	1987
10	Zj 928-P1	120501008	157-06-17311-22-02-0009	Zoje double ms	1	2006
11	LK-19004-HS	2LlIJ00469	157-06-17311-22-02-0005	Juki bar tucker	18	2001
12	LUH-521	Jo3399	157-06-17311-22-01-0114	Juki ms double needle	1	2006
13	2J9610	110301007	157-06-17311-22-01-0009	Zoje for sho e	3	2006
14	Lu-2266 N-7	218EJo1693	157-10-17311-22-01-0026	Juki double needle	2	1990
15	L52-01	8334635	157-10-17311-22-01-0016	Pegasus over locr	1	1990
16	LK3-P434-T48	J8589636	157-10-17311-22-02-0002	Brother bartucker	1	2006
17	ZJ428-P1	120501010	157-10-17311-22-01-0011	Zoje double needle	1	1987
18	LU2490	771524	157-10-17311-22-01-0005	Mitsubishi Single needle	11	1987

19	-	7085100079	157-10-17311-22-01-0025	Gemsy sewing mc	8	1987
20	GEM11888	7805100093	157-07-17311-22-02-0060	Gemsy Button hole	1	1998
21	GENSY-500-01	50093010405	157-07-17311-22-02-0058	GEMSY	1	1999
22	DBK-D	4881	157-05-17311-27-03-0002	Band knife	2	1987
23	ESCORT	1012212	157-05-17311-27-03-0003	Hand 11KM	10	1987
24	BS-201	110596	157-05-17311-22-04-0001	Bestonom drilling mc	1	1987
25	Mareew	14102763	-	Hand knife cutting mc	2	2009
26	SF-Type	771628	157-05-17311-22-05-0001	Sewing mc	1	2009
27	DO1-2	DOl-2-200012-020	157-05-17311-22-06-0002	Electrical steam boiler	2	2013
28	CO-3	12/01	157-05-17311-22-07-0001	From packing mc(Alba)	20	2013
29	CO1	12/02	157-05-17311-22-07-0002	Trouser topper horizontal	11	2013
30	AD-Heavy duty		157-06-17311-22-09-0001	Sherit	1	2013
31	ARSH-500		157-06-17311-22-05-0001	ALPHA Step sealer	16	
32	MAX-03	080609217		Yuki hailate	14	
33	Variant-T1	1604110978		Hot air welder	1	2009
34	Variant-T2	1604059267		Hot air welder	1	2009
35	Leister	1409189485		Hot air tool triacST	1	2009
36	KS Auv	870711	157-10-17311-22-03-0003	Mach km cutting machine	13	1990
37	BS-201	1100590	157-06-17311-22-04-0003	Bestman drilling machine	2	2006
38	DBK1-D	4879	-	Band knife machine	1	2006
39	ETWA	TR17.S	-	Escort cutting machine	12	2009
40	Marrew	14102740	-	Band knife machine	2	2009

C- **Available machine tools in Embroidery workshop**

No	Model	Factory S/N	Foundation S/N	Type of machine	Qty	Purchased date
1	J9701B-D3/P	11062570	157-14-17311-01-0008	Zoje single needle	18	2006
2	BRCS-%	07010015	157-14-17311-22-18-0002	Embroidery north prenix	12	2006
3	TNB-C902	7010003	157-14-17311-22-18-0002	Embroidery sampling mc	1	2000
4	TNB-C903	-	157-14-17311-22-12-0001	DAHAN laser	2	2000
5	12002026	1200885	157-14-17311-22-13-0001	Printer silk strich	1	2006
6	12002082	1200886	157-14-17311-22-14-0001	Printer silk mixer	1	2006
7	-	12002026	157-14-17311-22-11-0001	Screen drive	1	2006
8	1200874	12002082	157-14-17311-22-15-0001	Fabric drive	1	2006
9	12021339	-	157-14-17311-22-15-0002	Screen driver	1	2006
10	1202/339	12021339	157-14-17311-22-16-0001	Printing mc sulfate	1	-
11	BRCS-S	97230692	157-14-17311-22-18-0001	Embroidery and Surpling m /c	1	1989
12	KM-560	81105255	157-12-17311-22-14-0001	Sun star single needle	15	2002
13		771639	157-12-17311-22-06-0001	Mitsubishi single needle	8	1987
14	NP-7A		157-12-17311-22-14-0001	Sewing machine for pp bag	1	
15	KS-f-350	771300	157-12-17311-22-06-0001	Impulse solar	1	
16		1012113	157-12-17311-22-14-0001	Escort cutting machine	1	2006
17		40181636	157-12-17311-22-06-0001	OMM machine waving	12	1989
18			157-12-17311-22-14-0001	Kyong yhe china 2 head	1	1992
19			157-12-17311-22-06-0001	Kyong hye china 4 head	1	1992
20			157-12-17311-22-06-0001	Bonus 2 head machine	2	1990
21		9923744	157-12-17311-22-02-0003	Muller machine waving	2	1992

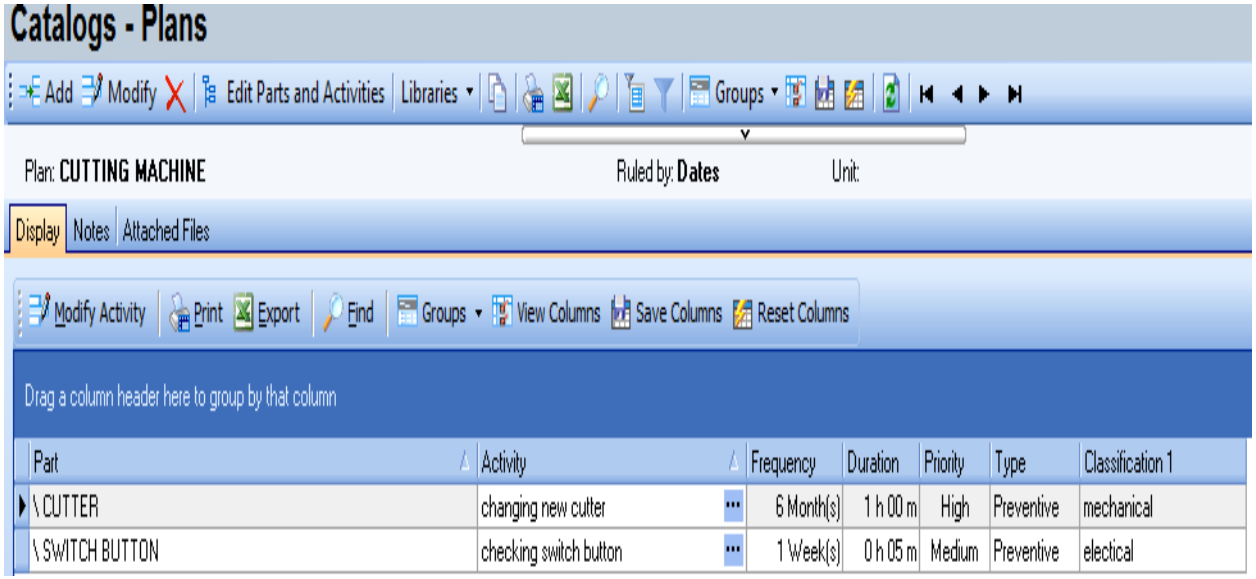
22			157-12-17311-22-02-0004	Warping machine	12	1989
23	LDMKESME	3321	157-12-17311-22-02-0005	Led max	1	2006
24	LDMKESME	69	157-12-17311-22-14-0001	Turkey weaving machine	2	2006
25			157-12-17311-22-06-0001	Hyalite machine turkey	1	2006
26			157-12-17311-22-02-0003	Compressor 500L	1	2006
27			157-12-17311-22-02-0004	Compressor 100L	1	2001
28	KJK-8700	60805537	157-12-17311-22-02-0005	Jack single needle	11	1999
29	Lu2-400	771539	157-12-17311-22-14-0001	Single needle Mitsubishi	1	1997
30	ZJ22905-sr		157-12-17311-22-06-0001	Zaji- zigzag	1	2006
31	LK-1903AN-ss		157-12-17311-22-14-0001	Button attach Juk	1	2006
32	LK-1900A-hs	2Lej00472	157-12-17311-22-06-0001	Bar taker Juk	1	2006
33	25928-PI	120501005	157-12-17311-22-02-0003	MS Zoji	12	2006
34	Lbh-17905	2LOFc00z37	157-12-17311-22-02-0004	Button hole Juki	1	2006
35	L52-01	8334225	157-12-17311-22-02-0005	Over lock (Pegasus)	1	1997
36	HPdisgaJect800		157-12-17311-22-14-0001	Plotter machine	1	1999
37			157-12-17311-22-06-0001	Electrical Steam iron	2	
38	Gem500-01	508300329	157-12-17311-22-06-0002	Cover stitch (gemsy)	9	1998
39	OMM-01	508300330	157-12-17311-22-06-0003	Weaving machine	2	1997

D- Out of Service machines due to spare part problem.

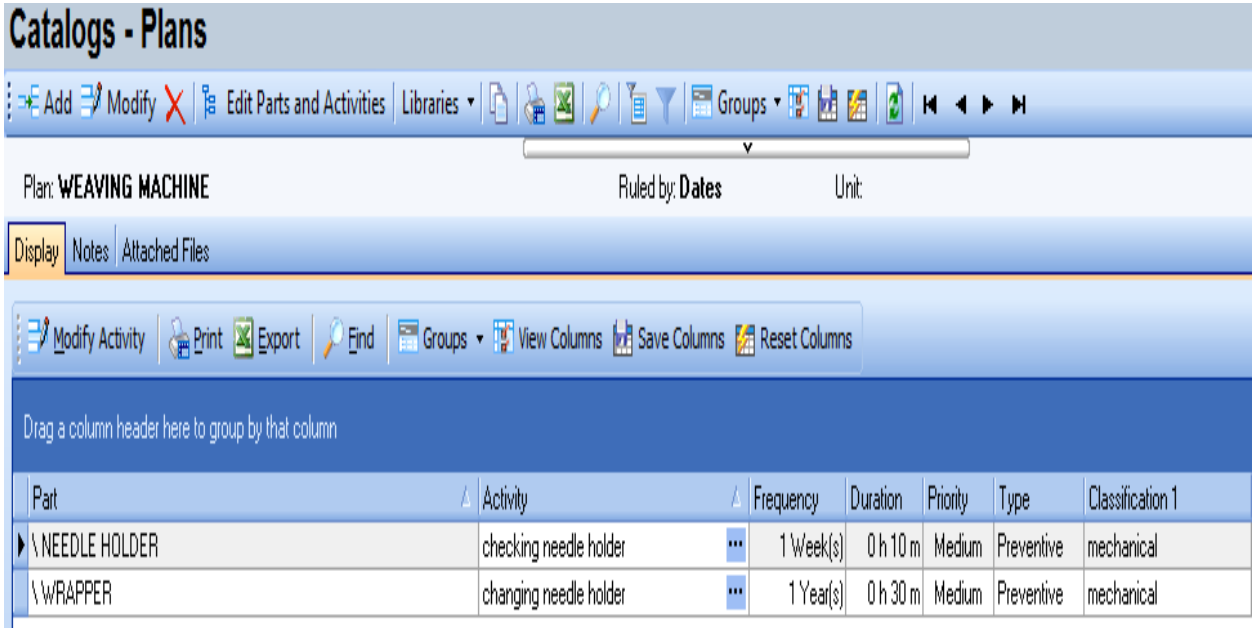
No	Model	Factory S/N	Foundation S/N	Type of machine	Qty	Purchased date
1	XH-93A	-	157-15-17311-22-20-0001	Printing machine	1	--
2	LT2-B838	H-9522969	-	Brother double needle	7	-
3	7050CX7050D	-	157-06-17311-22-10-0006	Brother double needle	1	-
4	-	-	157-06-17311-22-10-0031	Single needle machine	1	-
5	-	-	117-06-17311-22-10-0030	Single needle machine	1	-
6	-	-	157-07-17311-22-01-0029	Singer machine(small)	1	-
7	-	-	157-07-17311-22-10-0032	Singer machine(large)	1	-
8	KM-560	81106287	157-08-17311-22-01-0001	Sun star double needle	2	2002
9	KM-572B1	81106290	157-08-17311-22-01-0018	Sun star double needle	3	2002
10	LU2-400	80910324	157-08-17311-22-01-0014	Mitsubishi single needle	3	1987
11	LK3-B434-T28	80910323	157-10-17311-22-01-0029	Brother double needle	1	1987

Appendix 4 Maintenance plan using CMMS for selected plant machinery

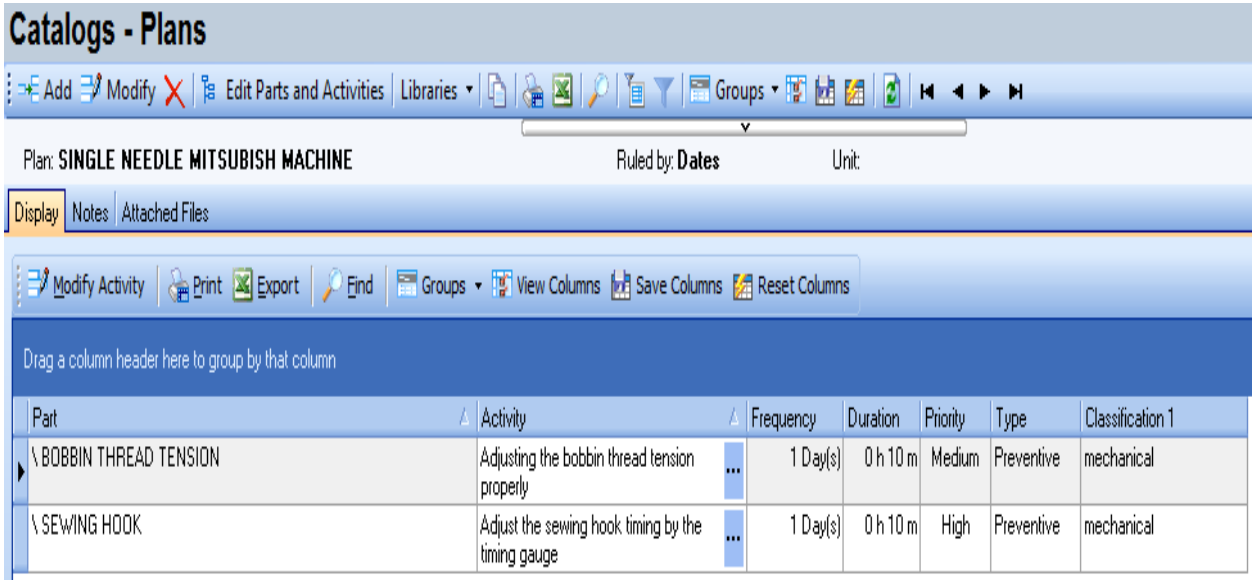
A- Maintenance plan for cutting machine.



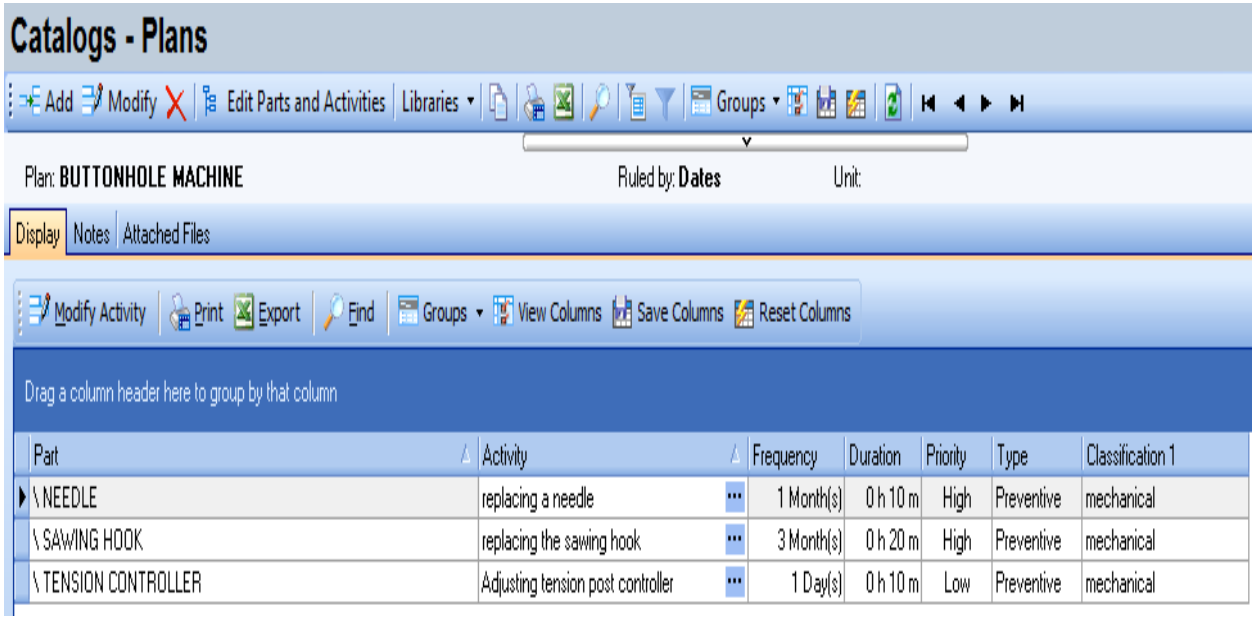
B- Maintenance plan for weaving machine.



C- Maintenance plan for single needle Mitsubishi machine.



D- Maintenance plan for Buttonhole machine.



Part	Activity	Frequency	Duration	Priority	Type	Classification 1
\ NEEDLE	replacing a needle	1 Month(s)	0 h 10 m	High	Preventive	mechanical
\ SAWING HOOK	replacing the sawing hook	3 Month(s)	0 h 20 m	High	Preventive	mechanical
\ TENSION CONTROLLER	Adjusting tension post controller	1 Day(s)	0 h 10 m	Low	Preventive	mechanical

E- Maintenance plane for brother single needle machine.