PRODUCTIVITY IMPROVEMENT IN ETHIOPIAN LEATHER INDUSTRY THROUGH EFFICIENT MAINTENANCE MANAGENET

By

Misikir Teklemariam

The Thesis Submitted to the School of Graduate Studies of Addis Ababa University in partial fulfillment of the requirement for the Degree of Masters of Science in Mechanical Engineering (Industrial Engineering Stream)

Advisor

Dr.-Ing Daniel Kitaw

Department of Mechanical Engineering

Addis Ababa University

June 2004

Content Page

List of Figures Page

List of Tables Page

List of Appendixes

Abstract

Increasing global competition has made many business leaders and policy makers turn their attention to such critical issues as productivity and quality. Productivity improvement should be a concern of every industry regardless of the type of production, economic or political system. The definition of productivity, the ratio of output value to input value, remains the same for every sector. Productivity can either be improved through increasing the output value by increasing the quality or quantity of products, or through decreasing the input value by utilizing the resources effectively & efficiently. Efficient maintenance management is one way of improving the productivity through capital resources of the company.

The paper examines how proper maintenance management improves the productivity of leather industries. Leather industry, as it is one of the potential economic sectors, it should be given proper attention for sustainable development of the country. Thus, the purpose of this paper is to propose improvement areas in maintenance activities of Ethiopian leather industries to improve their productivity by analyzing the problems associated with it.

CHAPTER 1

Introduction

With increasing automation and mechanization, production processes are shifting from manual to machines. Consequently, the role of equipment maintenance in controlling quantity, quality and costs is more evident and important than ever. To succeed in this new environment, equipment must be maintained in ideal operating conditions and must run effectively.

The link between productivity improvement and maintenance is well established. Proper maintenance maximizes the performance and availability of machinery, which leads to increased productivity. Equipment effectiveness is no longer restricted to availability, but involves other factors, such as quality and efficiency. That is defects and variations can be eliminated at their source. In particular, machine performance problems are identified early on. Therefore, one of the main areas for productivity improvement is maintenance and so the paper focuses on how to improve the productivity of Ethiopian leather industries through effective maintenance management.

This paper is organized as follows. This Chapter introduces the background and objective of the paper with the overview of Ethiopian leather industries. Chapter 2 contains productivity and maintenance concept, which is used as the theoretical background for the proposed improvement. The methodology, how this research is conducted, is described in chapter 3. The data collection and analysis for Ethiopian leather industries in general and particularly for Ethiopia Tannery S. Co. is discussed in chapter 4. Chapter 5 indicates improvement areas in Ethiopia leather industries maintenance practice. The last chapter, conclusion and recommendation, underlined the facts as well as opportunities the industries should attain. The appendices, which present the necessary information concerning the work, are attached at the end of this paper.

1.1. Background

Overview on Leather Industries in Ethiopia

The leather industry is one of the many economic sectors, which should be given attention for the development of our country. This sector is one of the leading industries playing a significant role in the generation of foreign currency, which ultimately the country utilizes, for developing all the other sector of its economy.

In the middle of the 1920s foreigners started modern tanning in Ethiopia. Addis Ababa Tannery is the first tannery established in the country. Currently, there are 20 tanners, which are operational in the sector employing about 6000 workers. Globally the leather and leather products industries have witnessed considerable shifts in the location of tanning and leather manufacturing to developing countries where production cost are lower and environmental regulation less stringent. Among other favorable opportunities the sector enjoys in the country, the global trend has also contributed significantly to the growth of the tannery industry in Ethiopia.

Ethiopia is one of the largest country in the world for its livestock resources and indeed the largest in Africa [12]. The data issued by the Animal and Fish Marketing Department of the Ministry of Agriculture and Rural Development in 1996 E.C. has estimated this resource to stand at 40.9 million cattle, 25.5 million sheep and 23.4 million goats [12]. This report issued by the ministry indicate that from its cattle resource Ethiopia is able to produce about 2.4 million hides, 8.3 million sheepskins and 7 million goatskins annually. The kill rate is also estimated to be 7%, 33% and 37% for cattle, sheep and goats respectively. In addition to this being a reliable and renewable source of raw material for the tanning industry and the leather goods sub-sector, it is also a source of meat, milk, fiber, fuel and fertilizer for the local consumption by the people.

The country has built a reputation for producing world-quality hides and skins. The leather sector is the second largest component of Ethiopia's export earnings after coffee; representing 12% of total earnings. Reports have indicated that the country was able to generate above US$60 million in 2004 from its leather industry [12]. The hides and skins

are partially processed for export, or are tanned and finished for footwear and leather goods industries. Backed by this enormous raw material base, the leather and leather products industry in Ethiopia has been operational for more than eighty years.

Within the manufacturing sector, the leather industry comes as the leading exporter accounting for, on the average, up to 67% of the total manufactured exports [12]. The leather and leather products sub-sectors produce a range of products from semi processed leather in various forms finished consumer goods of leather garments, stitched upholstery, shoe uppers, handbags, industrial gloves, school bags and finished leather. The country is exporting these products mainly to markets in Europe, the USA, Canada, Japan, the Far East and the Middle East countries.

To increase the level of value added retained in Ethiopia from the processing of its raw materials, the Government requires that all new investments in the tannery sector be capable of processing hides and skins up to the crust or finished leather stages, within three to five years of commencement of operations. Thus, most of the tanneries are working on the issue.

Background of the Thesis

Productivity refers to the effectiveness of working, not its intensity. Productivity can be improved through human resource or capital resource. Maintenance management is one way of improving productivity through capital resource. 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 out put 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.

As we discussed above, leather industry is one sector from which Ethiopia benefits 12% of the total earnings through exporting leather products. Therefore maintenance management system in leather industries should be well systematized in order to decrease the failure of the machines due to unplanned maintenance systems. Maximizing the availability of an equipment or machinery is the most significant short and long-term contribution that the maintenance management can make. So it increases the efficiency of the output.

An effective processing and/or manufacturing equipment maintenance program might be characterized as the product of prudence. Good maintenance programs and the efficient management systems behind them are essential for economically viable and operationally safe machinery. But during my visit I observed that most of the leather industries 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.

Compared to having no maintenance program at all, the allocable equipment maintenance costs may increase, but the value of improved equipment productivity through efficient maintenance management is greater. 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. Whatever the organization harmony is appropriate for the equipment maintenance program its goals and procedures should be formally documented, and it should not be 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 profitability.

1.2. Problem Statement

These days, survival of any company is strictly on its competitiveness in the market. The competition may be in a national or international level. As technology grows fast, management system becomes more computerized to increase efficiency in every dimension. Most organizations in Ethiopia lack efficient maintenance management system that affects the total output. Maintenance has received little notice in most organization, which makes the availability of the machines to decrease. That directly affects the productivity of the organization. Leather industries are one among these that lack efficiency in maintenance area. Most leather industries face problems on maintenance management system, so they lack activities like:

- Keeping historical records of equipment,
- Preventive based maintenance operation,
- Maintaining equipment properly at the right places,
- Decreasing the down time of equipment
- Inspecting the equipment in scheduled interval
- Controlling the performance of the equipment frequently
- Planning order of spare parts, lubricants, fuels and others
- Proper handling of lubricant and chemicals.
- Proper communication of the machines with the reference catalog for order processing and maintenance activity.

Since maintenance costs are very high for most organization, much attention is being turned to accountability for maintenance expenditures. As organization audit their maintenance cost, they find a sizable amount of money spent with little management control. Proper maintenance must be applied to maintenance if costs are to be limited. Thus implementing efficient maintenance management system improves the productivity of the industries by minimizing the above problems to maximize productivity.

1.3. Objective of the Thesis

Taking the above problems in to consideration, this thesis focuses on accomplishment of the following objectives.

- To find out an optimum balance between high maintenance cost and low machinery down time which maximize the profit.
- To analyze the above problems and propose a model for effective maintenance management system considering the present maintenance system in Ethiopian leather industry by:
    - Thoroughly analyzing the problems in maintenance management system that lower productivity
    - Identifying causes of the problems
    - Suggesting possible solution to improve productivity through maintenance management system.

Finally, a computer program will be developed to handle the maintenance management system of leather industries.

CHAPTER 2

Literature Survey

2.1. The Concept of Productivity

Formally defined, productivity is a summary measure of the quantity and quality of work performance with resource utilization considered. Regardless of the type of production, economic or political system, the definition of productivity remains the same. Thus, though productivity may mean different things to different people, the basic concept is always the relationship between the quality and quantity of goods or service produced and the quantity of resource used to produce them. It can be measured at the level of the individual, group, or organization. From a manager's perspective, productivity in all cases reflect success or failure in producing goods and services in quantity, of quality, and with a good use of resources. In short it is the ratio of output value to input value. This concept is expressed in the productivity equation [1].

$$\text{Pr}\,oductivity = \frac{Output\ Value}{Input\ Value}$$

The equation shows the productivity rises, keeping other things constant, when the quantity of outputs increase, the quality of output increases, and/or the cost of resources (input) utilized decreases.

The performance of an organization cannot be judged by the increment of the quantity of the output alone. The output may be raised without an increase in productivity. That means the rate of the increment of in put cost may be higher or the quality of the output may be decrease.

The concept of productivity is also increasingly linked with quality of output, input, and process itself. Taking the definition of quality as conformance to requirements of the customer, productivity decreases as the quality of the output decrease. For example, in

leather products, quality means leather without any defect on it. According to the number of this defect per square feet the grade of leather decreases from first grade to second grade, third grade, …The value of the leather produced dramatically decreases as the grade of it decreases from 1, 2, 3…. This quality problem may come from skin disease during the animal life, improper slaughtering and skinning, bad preservation and improper processing in the factory. Therefore, the quality of the in put and the process itself also affect productivity.

Productivity is also linked with how the resources are utilized in the company. It is the function of achieving the maximum possible with minimum resource. The resources are manpower, material, equipment, spares and building, capital and time. The responsibility of achieving higher productivity rests on managing these resources efficiently. By definition productivity doesn't come from working harder. This may increase output, but it also increases labor input. Similarly, using more capital or other production factors do not necessarily increase productivity. Productivity growth comes from working smarter. This means adopting new technologies or new techniques for production.

Productivity can also be defined as the relationship between result and the time it takes to accomplish them. Time is often a good demonstrator since it is a universal measure, and it is beyond the human control. The less time taken to achieve the desired result, the more productive the system is.

Generally, productivity should be considered as a comprehensive measure of how organizations satisfy the following criteria.

- Objective: the degree to which they are achieved.
- Efficiency: how efficient resources are used to generate useful output.
- Effectiveness: what is achieved compared with what is possible.
- Comparability: how productivity performance is recorded over time.

2.1.1. Productivity Measurement

Productivity is not a complicated concept as it is discussed above. It is the amount of output produced per unit of input. While it is easy to define, it is notoriously difficult to measure, especially in the modern economy. In particular, there are two aspects of productivity that have increasingly challenged precise measurement: output, and input. Properly measured, output should include not just the number of product coming out of a factory, but rather the value created for consumers. In today's economy, value depends increasingly on product quality like appropriateness, customization, convenience, variety and other intangibles.

Similarly, a proper measure of inputs includes not only labor hours, but also the quantity and quality of capital equipment used, materials and other resources consumed, worker training and education, even the amount of organizational capital required, such as supplier relationships cultivated and investments in new business processes [9].

Productivity is a comparative tool for managers, industrial engineers, economists and politicians. To be useful, measures must be as simple and as consistent as possible. When deciding to measure productivity, consider what a person does, how well, how much, and how often [7].

2.1.2. Productivity Factors

There are a number of ways to classify productivity factors. Among those the most general one is classifying it in to external and internal factors. The external factors are those, which are not controllable by the organization itself and the internal factors are those within its control. Thus the first step towards improving productivity is to identify problem area within these factor groups. The next step is to distinguish those factors, which are controllable [9].

The external factors that affect productivity are the economical, political, social, and other infrastructure factors, which influence the effectiveness and decision making process of the

enterprise management [9]. However the management cannot control these external factors in short run. The internal factors, which can be controlled in short run, are product, equipment, technology, materials, energy, people, organization and management style [9]. Each factor is discussed briefly below.

Product

Product as a factor of productivity means the extent to which the product meets the output requirements. The amount that the customer is prepared to pay for a product of given quality is determined by the product value. The value of the product can be improved by better design and specifications. The availability of the product at the right place, at the right time and at the reasonable price with the needed volume can also be important factors that affect the over all productivity.

Plant and equipment

Plant and equipment productivity can be improved by: operating the plant and equipment in optimum process condition, good maintenance, eliminating bottle-necks, reducing idle time, and making more effective use of available machines and plant capacity. The productivity of industries, which produce perishable products or products that degrade unless continually processed, like leather industries, is highly dependent on their equipment. That means, the equipment used should be kept well and be available by proper maintenance to avoid the decomposition of the hide or skin on process.

Technology

Increased volume of goods and services, quality improvement, new marketing methods, etc… can be achieved through increased automation and information technology. Automation can also improve material handling, storage, communication system and quality control. Thus the technology can be one of the important factors. For leather industry sector the quality of the finished leather is highly depend on the technology used. That is why most of the leather products exported from our industries are usually in semi-processed form.

Materials and energy

By reducing the amount of material used and energy utilization the productivity can be remarkably increased. These vital sources of productivity include raw materials and indirect materials like process chemicals, lubricants, fuel, spare parts, engineering materials. Electrical or other source of energy must also be optimized to increase productivity. Processing industries like leather uses chemicals intensively, thus the total cost of these industries can be decreases by reducing this inputs. For example, it is possible to save 60,000Birr/annum in Ethiopia Tannery S. Co. by reusing the exhausted chrome through chrome recovery plant [14].

People

All people, managers and workers, in the organization have a significant role to play in productivity. The productivity depends on the degree to which people's commitment to their work. People differ not only in their ability but also in their will to work. Therefore, motivation is one method to increase productivity.

Organization and management style

An organization needs to be dynamically operated and led towards objectives and must be maintained, serviced and reorganized from time to time to meet new objectives. Management styles and practices also influence effectiveness through organizational design, personnel policies, operational planning and controlling, maintenance and purchasing policies and capital costs.

2.2. Productivity Improvement

Productivity improvement is not just doing things better; it is doing the right thing better [7]. Productivity can be improved by utilizing the resources effectively. Thus the resources can be grouped in to human and capital resources. The brief descriptions of these two resources are discussed below.

I. Productivity Improvement through Human Resources

The productivity issue of resource utilization includes another significant concern in today's world of strong social values- the way people are treated as human resources in the workplace. Human resource is the most important and potential area of productivity improvement [22]. Ideally, productivity is achieved through high performance with a sense of satisfaction by the people doing the work. The term quality of work life is an indicator of the overall quality of human experiences in the work place. Managers are increasingly expected to facilitate productivity for the organization while maintaining the quality of work life for its members.

The main management responsibilities in a productivity drive are to identify the objectives, to setup a productivity improvement program and to establish a productivity measurement system [9].

Identifying the Objectives

To start any productivity improvement program, management has to identify the area where improvement is necessary and achievable. And also it has to identify the specific elements of productivity that are critical to the enterprise's success such as quality, quantity, customer satisfaction etc.

Setting up a Productivity Improvement Program

The structure of the organization must be carefully examined in order to identify the changes to be aimed at the productivity improvement program. In spite of the difference in enterprises goal and approach, the following checklist for establishing a productivity improvement program is suggested: [9]

- Top management has a key role in determining the need for a maintenance program and initiating, developing and adopting of a productivity improvement policy.
- A team which includes all parties concerned has to be formed. Outside consultant may be called in.
- A small unit can be established to carry on a productivity program

- Educating management and supervisors in productivity improvement is crucial.
- Personnel at any level should be involved through group meeting and informal discussion at the plant, departmental or office level.
- The program should provide for a periodic review and evaluation of results. This requires the establishment of measurement and goal for each organizational unit.
- It is vital to raise the awareness level within the organization of all the factor that will influence the productivity and of the system for improving it.

Establishing Productivity Measuring System

One of the important steps in productivity improvement is establishing a productivity measurement system within the organization. This in itself brings some improvement in performance by making people more aware of the meaning of productivity. The measurement system must consider cost effectiveness, and determine the range and terms of measurement system tasks. It must be easy to use and serve to identify the reasons to organizational changes.

II. Productivity Improvement through Capital Resource

Significant productivity improvement usually comes from saving material and energy. On average, raw materials account for about 40 percent of total national production cost; if we include energy, this figure increases considerably [9].

Poor operator practice, bad layout and inadequate storage space can aggravate problems in handling materials and lead to excessive movement. A significant objective of any productivity improvement program should be to suggest method of maintaining the volume of production while reducing consumption of energy and materials and substituting cheaper materials and spare parts for costly ones keeping the quality constant or better. Alternatively, a productivity program should suggest ways to produce more from a given quantity of raw material. Improving productivity also depends on optimal choice and utilization of materials and energy resources.

It is the operators and foremen who actually control the utilization of materials, energy and machines, but managers, production engineers and quality assurance staff still have important responsibilities in the area. Energy conservation and materials waste reduction must be undertaken at several levels, from the organization level down to that of the operator. Energy conservation can be achieved by recovering wasted heat and/or resources.

Quality is also the one way of improving productivity through capital resources. It can be defined as the sum of features and characteristics of a product or service that bear on its ability to satisfy a given need. This includes economic need as well as availability, easy maintenance, reliability, design and all the other characteristics of need.

Basic elements of product quality are: performance, features, reliability, conformity, durability, serviceability, aesthetics and perceived quality. Recognition of this basic element is important for productivity. An organization that chooses to improve quality can do so in several ways; it need not pursue all elements at ones. Instead, a segmentation strategy can be followed with a few dimension singled out for special attention. Thus, quality is one of the important factors and area of productivity improvement, and quality management is an important tool for productivity management.

The other way of improving the productivity through capital resource is maintaining equipment properly to make them available whenever needed. It is discussed below, as it is the core of this research.

2.2.1. Productivity Improvement through Maintenance

Improvement of capital productivity is the ultimate objective of a good maintenance management system. Productivity is affected by the volume, variety and period of operating fixed capital. The quality, age of the equipment and degree of sophistication usually weigh heavily in any measure of an organization's productivity [7].

It is not uncommon to find less machine utilization due to poor planning and lack of preventive maintenance. In one comparatively successful productivity improvement drive, downtime on critical production equipment should reduce in considerable amount. That means the availability of machines increases and so the productivity.

As it is stated above productivity increases when the quantity of out put increases, other things being constant. Thus, proper maintenance makes the equipment to be available whenever needed. So the amount of output produced increases. But industries in developing countries have a problem of minimizing the number of breakdowns, which greatly affect productivity of the company.

On the other hand, the total cost of any company can be decreased if the resource utilized is decreased. Productivity improvement in this way can also be achieved if planned maintenance system is practiced. By having a planned maintenance system, the total cost of the company can be reduced through lowering the costs of spare parts, overtime, and other related costs.

Good maintenance system also assures the equipment effectiveness. Quality is a key factor in measuring equipment effectiveness. Quality improvement means minimization of waste and defective products, which increases productivity and often leads to cost reductions. Thus good maintenance system increases productivity by improving the quality of products.

2.2.2. Productivity Improvement Techniques

The techniques used in carrying out productivity improvement programs are mostly for collecting information and increasing the effectiveness of work [13]. Two of the techniques that are used to improve the maintenance function are: method study and work study.

i) Method study

Method study is the systematic recording and critical examination of existing and proposed ways of doing work in order to develop and apply easier and more effective methods and to

reduce costs. Its philosophy is that there is always a better way of doing things. It consists of systematic analysis of the present method and bringing about improvement through critical examination. The steps are:

- Select the work to be studied.
- Record from direct observation everything that happens.
- Examine the recorded fact critically and challenge everything that is done.
- Develop the best method under the present prevailing conditions.
- Install the method chosen as standard practice.
- Maintain the standard practice by regular checks.

Better layout of workplace, improved utilization of resources and improved working condition are some of method study contributions.

ii) Work study

Work study is a term that denotes the techniques of method study and work measurement which are employed to insure the best possible use of all the available resources, labor and material, in carrying out a specific activity [13]. It is specifically concerned with productivity since it is used to increase the amount produced from a given quantity of resources without further capital investments. Hence, work study is of interest to a manager, because it is concerned with all the resources a management process, and their systematic improvement so that they are efficiently and effectively utilized.

The aim of work study is to improve productivity and not to make the worker be more work harder. That is productivity will not always need working harder but smarter. Moreover, work study needs to be applied continually to update and bring for further improvement.

2.2.3. Productivity Improvement Strategy

A sound productivity strategy calls for a system approach, which recognizes the inter-relationship between the elements of the system with their environment, to productivity improvement. It defines the performance of the system and maintenance equilibrium while effecting changes.

Thus productivity strategy is the pattern of decisions in the organization that determine its objectives, procedure and principal policies and plans for achieving long-term productivity improvement goals. A good productivity improvement strategy should: [9]

- develop a clear and easy communicated definition of the productivity improvement concept;
- explain why organizational improvement is important;
- evaluate current operating status and the reasons for the current status;
- develop model for excellence;
- develop improvement policies and plans.

Organization with clear productivity concepts should set a clear objective. The objective of productivity improvement should always be expressed in terms of organizational improvement in recognition of the past and current success of the division and subsidiaries within an organization.

2.3. Maintenance and Production

A maintenance department cannot operate in an isolated environment and must be integrated with other departments of the organization. Whenever the work imposes on the operations of other departments, the plan should be coordinated for concurrence, then stated in written form and distributed to all concerned members of management. Thus, to increase the maintenance activity of maintenance department it should adjust itself with other departments before starting the work orders.

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. This is shown in the figure 2.1

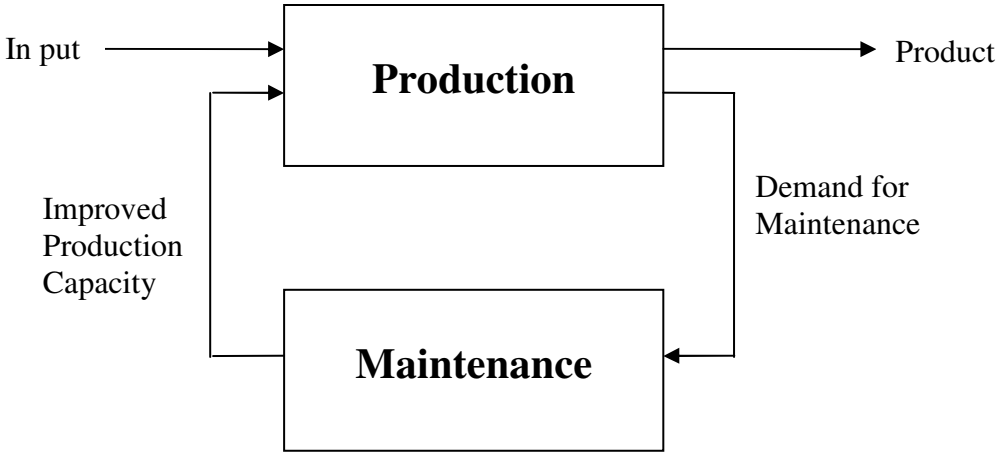

Fig 2.1 Production - maintenance relationship

The role of maintenance in accomplishing production objectives is by maintaining equipments to make them available whenever required. However, much work should be done to integrate maintenance and production. In most cases, maintenance is viewed as a limiting constraint and the problem is how to meet the production master schedule under maintenance constraints. Integration of maintenance and production has to be based on a clear understanding of their relationship. In the production and inventory analysis, the economic production quantity (EPQ), the amount of product, which can be produced profitably without affecting the quality, has been studied under various conditions. However, a more realistic situation is one in which the quality is not always acceptable, because the condition of the production process may deteriorate with time. To minimize the expected total cost of such a deteriorating system, the EPQ and maintenance schedule should be jointly determined [4].

2.4. Types of Maintenance Philosophy

There are six types of maintenance philosophy that determines the amount of service required from the equipment and resultant cost. These are listed below: [2]

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 generally below acceptable levels with product quality usually impacted. Equipment is never taken offline for maintenance. It allows for a lower skill set, as the failure are usually well defined. And, there is no requirement to purchase extra parts or labor, because there are 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 (from item 2) 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 do 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 can be 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.

2.5. Maintenance Approaches

Maintenance technique used can very highly affect maintenance performance. The cost of repairing in reactive mode (in corrective maintenance mode) is on average about three times higher than the cost of repairing in preventive mode (in preventive maintenance mode) and also has less performance than preventive mode [2]. This is because the reactive maintenance does not tackle the root level of a problem and always results in repetitive failure.

Many organizations tend to adopt the proactive maintenance philosophies such as Total Productive Maintenance (TPM) and Reliability Centered Maintenance (RCM), because these two approaches are committed to long-term improvement of maintenance management especially for those, which process perishable product, like leather industry. Let's discuss the two approaches in brief.

I. Reliability Centered Maintenance (RCM)

The most significant strategic change to impact the management of physical assets is known as Reliability Centered Maintenance (RCM), and incorporates within it several distinct shifts in the way we view physical assets and their upkeep.

The power of RCM is not in doubt. There is more than enough hard evidence from manufacturing, extractive, transport and process industries that prove the technical value in establishing and improving system maintenance. It is however a sharp tool, and is usually best applied in selected areas rather than broadly across a facility. To achieve worthwhile results, it must also be carried out by (or at least with) the actual operators and maintainers of the systems. RCM is not a "quick fix" solution, time and effort must be invested on training, raising awareness, execution and implementation.

It does however achieve an understanding of how the plant works, what it can (or cannot) achieve, and the causes of failure. By doing so it focuses maintenance effort on those areas where it is beneficial. The analysis itself is carried out in groups consisting of experienced supervisors, and specialists. These groups set up maintenance tasks and an ownership concept is developed.

The development of RCM had lead to a radical change of direction in our understanding of maintenance and its performance leads us with entirely new concepts. Today, maintenance directly influences the core aspects of modern business; safety and environmental integrity, energy efficiency, quality, uptime and costs. RCM can be formed as the core of any effective maintenance policy, therefore it should be at the heart of our business [15].

II. Total Productivity Maintenance (TPM)

TPM is a manufacturing led initiative that emphasizes the importance of people as one of the factor that can bring about the efficient maintenance management. It is presented as a key part of an overall manufacturing philosophy. In essence, TPM seeks to reshape the organization to liberate its own potential.

The machine operator is the key player in a TPM environment, since one of the main causes of breakdown comes from abusing operation and lack of primary care from the operators. Thus, to have efficient maintenance management, the involvement of operators is very vital. There is less reliance on the maintenance department for basic maintenance control and responsibility passed to the operator. The operator goes through seven steps to reach full autonomous maintenance [10].

1. *Initial cleaning, reviewing of entire machine, tightening:* - Complete cleaning of machine. Repair any deficiencies that become apparent during the complete cleaning. Tighten all fasteners to specification. Review entire machine operation.
2. *Inspection:* - Initial inspection follows manufacturer's manuals, engineering recommendations and equipment history. Group is taught how to correct minor defects.
3. *Maintenance prevention:* - Reduce time to perform cleaning. Remove source of contamination. Make the machine easier and quicker to service.
4. *Establish consistency:* - Specify all tasks and frequencies (daily, weekly…). Set standards for tasks. Properly document all tasks.
5. *Autonomous inspection by operators:* - Inspection is turned over to the operator group. Check sheets are utilized for inspection. Minor repairs are completed. The maintenance department is involved only in major problems that needs specialized knowledge or skill.
6. *Organization to support ongoing TPM:* - Systematize the autonomous maintenance activity. Align the organization to support TPM. Use the TPM productivity reports to run the plant. Develop standards for all activity.

7. *Full functioning:* Truck the result of the effort and give ongoing recognition to progress. Minimize minor failure frequency and look for additional improvement. Spend more time for improvements, which reduce maintenance effort while increasing equipment availability.

TPM is concerned with the fundamental rethink of business processes to achieve improvements in cost, quality, speed etc. It encourages radical changes, such as; [4]

- Flatter organizational structures - fewer managers, empowered teams,
- Multi-skilled workforce,
- Rigorous reappraisal of the way things is done - often with the goal of simplification.

It also places these changes within a culture of betterment underpinned by continuous improvement monitored through the use of appropriate measurement.

Some of the Benefits of TPM includes:

- Better understanding of equipment criticality and where it is worth deploying improvement effort and potential benefits,
- Improved teamwork and a less adversarial approach between Production and Maintenance,
- Improved procedures for changeovers and set-ups, carrying out frequent maintenance tasks, better training of operators and maintainers, which all lead to reduced costs and better service,
- General increased enthusiasm from involvement of the workforce. [4]

2.6. Maintenance Management

Maintenance management is the direction and organization of resources in order to control the availability and performance of an industrial plant to a specific level [14]. It also refers to the application of the appropriate planning, staffing, program implementation and control methods to the maintenance activity. Often, decision making is concerned with optimal allocation of resources to various activities with the final aim of lowering the operating costs by increasing reliability, availability, quality and safety. Maintenance is seen as a

strategic functional area, which has the potential to reduce the overall cost while improving the quality, productivity or availability and reliability. The basic functions of maintenance management are discussed below.

2.6.1. Maintenance Planning and Scheduling

Planning and scheduling functions are the key deliverables of the maintenance management role. In some larger organizations planning and scheduling are split, allowing more adequate resources for each role. The difference between planning and scheduling is that, planning is the job of looking in to the future and anticipating the resource needs of a project or repair, but scheduling is the execution step of the planning process. Let's see both in detail:

Planning

Planning involves the selection of the objectives and the determination of the policies, programs and procedures to be used for achievement of the selected objectives. Because it involves selection among alternatives, planning is decision making. Of all management functions planning is one that permits a maintenance department to act rather than react. When given proper attention, it is the function that facilitates the maximum utilization of available labor, money and material resource. Planning, however, is the function that often receives the least emphasis. This lack of emphasis causes much of the criticism labeled at maintenance department for being too costly or unresponsive to the organization's needs.

Planning can occur at any stage during the life of a works order. A works order requires parts, procedures, documents, skills and equipment. A work order cannot be considered planned until all of these have been considered.

Plans are sometimes classified based on the period of time they have been designed to cover. Long-term plan normally projects three to five years in to the future. Short-term plans normally cover a time span of one to three years. Near term plans cover monthly and quarterly time periods. [2]

Long-term Plan

Some maintenance managers claim that long-term plans are impossible to develop, because they just cannot correlate meaningful information. But it can be meaningful, provided they include elements or objectives that can be predicted with a reasonable amount of certainty, such as: replacement of maintenance department shop equipment, and retirement or replacement of permanent maintenance department employee.

Short-term Plan

Short-term is easier to develop than long-term plan. Normally it should contain considerably more detail for the first year covered than for the succeeding year. The last two year of the plan are more generalized, showing categories of effort and major programs to be started, accomplished or completed. The first year of the short-term plan should interface directly with the established budget for the year.

Near-term Plan

Near-term plan contains detail and represent the operating plan for each month or week in the period covered. It also contain the milestone dates for each maintenance job being performed and the number of man power allocated to breakdown, repair, preventive maintenance and so on. Thus the near-term plan constitutes an allocation of resources to the various functions or type of work to be performed by the maintenance department.

Scheduling

Maintenance Scheduling is the matching of maintenance labor and material resources to the requests for the maintenance labor and material resources. The flow of scheduling starts with good job plan, statusing the work order, scheduling the work when resources are available, completing the work.

When planning the work order, the planner needs to track the work order through various status codes like: ready for schedule, in process, completed, canceled. A planner would want to ensure that the work order has cleared and ready to schedule. Scheduling the work before it can be started decreases maintenance productivity.

Good scheduling also necessities knowing the amount of work skill to be performed by each craftsman; this is commonly called craft backlog. The formula for accurate measuring the craft backlog in week is open work orders ready to schedule (total hours) divided by craft capacity (weekly). Knowing this helps to determine the staffing requirement for the craft group [2].

Quantifying Plans

Unless plans are defined in terms of numbers as well as time, they will probably remain dreams. Effective planning necessitates quantification. It is not expected to perform effectively without quantifying what it is doing and what it intends to do in the future. Therefore to most effectively communicate with top management, the plans of maintenance department should be expressed and quantified in terms of dollar/birr [3].

However, there are other methods of quantification that can be used by a maintenance department to express plan. Some of these units of measure are headcount and labor hours. These planning techniques facilitate the execution of both the staffing and controlling functions.

Setting priority systems

A priority system for jobs is used to define the order of precedence in assigning the accomplishment of specific work orders involving emergency/breakdown, modification or preventive maintenance activities. Normally, the method establishes subcategories such as: top priority, second priority, and routine priority [4].

Top priority – work requires immediate action, taking precedence over all other work to be scheduled. Emergency/breakdown work can be taken as an example. Normally, the assignment of a top priority is limited to work seriousness because of health, safety or security requirements or performance of operations essential to the organization serviced by the maintenance department.

Second priority - is assigned to work requiring expeditious handling to assure completion on a specific date to support operations. Here modification work can be taken as an example.

Routine priority – is assigned to work orders that may be accomplished on a first-in-first out work schedule cycle where no specific need date has been established by the requester.

2.6.2. Organizing the Maintenance Department

The management function of organizing is the development of the organization structure and authority-relationship required to achieve selected objectives. Therefore, organizing the maintenance department means the grouping of activities necessary to achieve the mission of the department and the assignment of each group to a supervisor. Proper performance of organizing can lead to substantial cost savings. These savings can be achieved in labor, material, and capital investment of the maintenance shop.

The maintenance department of each organization should tailor its system to best meet its own particular mission. There is no one best way to organize, but there are three basic tasks, which are necessary for efficiency in cost and performance. These are: [3]

1. Determining what work has to be performed (i.e., specifically defining the department's mission and the emphasis to be placed on the various types of work)
2. Deciding what work belongs together (i.e. the grouping of the functions to be performed)
3. Determining how the work is best accomplished.

The accomplishment of these three tasks should not be a one-shot effort. A maintenance manager should be prepared to perform them periodically since conditions do not remain constant. Now let's discuss methods of how maintenance operation should be performed.

Methods of Operational Maintenance

Here we will discuss two methods of operational maintenance: individual assignment and structured organization, which are stated as follow.

1. Using Individual Assignment

In a small maintenance operation the individual assignment method is normally the most efficient. The maintenance manager personally directs the individual personnel who are assigned on a day-to-day basis to accomplish the work

Eventually as the department increases in size, personally directing all of the craftsmen is no longer effective for the operations to be performed. If the department begins to operate on more than one shift, the feasibility of personally directing all of the craftsmen rapidly declines. Because there are too many details and too many decisions to be performed by the manager. The maintenance manager who insists upon trying to do everything will find that he can no longer concentrate on the matters at hand, let alone do any planning with respect to organizing, staffing, controlling or directing. It is time for an organization to be structured [3].

2. Structured Organization

When a structured organization is created, it consists of a grouping of coordinated sections, managed by a foreman or supervisor who acts with the authority of the maintenance manager on certain delegated functions. For the maintenance department there are three basic methods for the organizing of the line operations. These are: organizing by operation, by zone and by shop [3].

i) Organizing by Operation

In its purest form, organization by operation would consist of a separate group for inspection, planned maintenance, repair, overhaul, construction, and salvage. Each of these groups would have a foreman or supervisor responsible for the activities performed.

Inspection would involve periodic inspection of equipment to insure safe and proper operation. That means assuring weather periodic maintenance is performed, controlling of the quality of work accomplished by maintenance craftsmen, inspecting materials and parts

received from vendors, examining the items removed during repair or overhaul operations etc.

Planned maintenance would consist of the lubricating; adjusting, routine and other planned activities.

Repair would consist of replacing parts to restore a piece of equipment to full operating condition and to alleviate undesirable conditions found during periodic maintenance or breakdown.

Overhaul would involve the reconditioning of equipment: teardown, replacement, reassembly and testing.

Construction and rehabilitation would consist of building, modifying and restoring structures.

Salvage would involve the reclamation and disposition of surplus material and scrap. In some companies collection and disposition of all surplus materials, equipment, and supplies is also often assigned to a maintenance department, since these operations are related the maintenance inspection activity.

ii) Organizing by Zone

A maintenance department organized on a zone basis assigns each maintenance group to a specific geographical location or area. The organization is geographically decentralized, with a foreman or supervisor over each group. The advantages of zone maintenance are usually considered to be: [3]

- Reduced travel time to and from jobs.
- More intimate knowledge of the equipment through repetitive experience with it.
- Improved job performance, due to greater interest resulting from a closer alliance with the objectives of a smaller group.

- More familiarity with the specific needs in the area serviced with improved relation between the users of the facilities and the maintenance department.

The main disadvantage to purely zone maintenance is the potential for inefficiency. There can be poor utilization of the labor force. In one zone the craftsmen may be busy up to their ears in trouble calls, while in another zone things are quiet and the men are performing low-priority work. Duplication of tool crib items and shop equipment with a low utilization rate can also result, since each zone group will endeavor to be self-sufficient.

iii) Organizing by shop

This type of organization is essentially centralized. The grouping is by craft shop. Each shop has a foreman responsible for all work done by his people. A shop may consist of one or more crafts. The advantages of a centralized shop organization are generally considered to be: [3]

- Easier dispatching with more specialization by craft skill within the maintenance department.
- Higher-quality equipment justified for use in larger central shops.
- Better interlocking of craft effort through central control.
- More specialized supervision
- Improved training facilities.
- Easier to assign skilled manpower

There are disadvantages to a strictly centralized shop organization. First, in a large complex of facilities there is an increase in travel time. Second, a central shop organization does not facilitate familiarity with the needs of a given area of the intimate knowledge of equipment necessary in some maintenance operations.

Establishing a Stockroom Operation

Classifying Stock

Any maintenance department is required to keep a supply of materials and parts on hand if it is to operate efficiently. Items that are continuously used, such as standard nuts, bolts,

screws, nails, and other hardware and high-usage materials (lubricants, woods, wires and so on), are generally referred to as *standard stock items.* For these items a minimum quantity is established and stock replenishment is initiated when the quantity on hand reaches the minimum quantity [3].

Items that are not part of the standard stock inventory are referred to as *special buy items*. These items are obtained on the basis of individual procurement requests, since there is no provision for a minimum quantity and automatic stock replenishment.

Low-value, but high-usage standard stock items are sometimes designated as *open stock*. Craftsmen can obtain them directly from bins without the use of a stock requisition form. There is no control over who takes the stock or record of what job it was used on. Those maintenance managers who use an open-stock operation claim that using a stock clerk to issue the material and process the requisition paperwork costs more than the material being controlled.

Using Sub Stores

When the maintenance department is organized on a zone or area basis, sub store sections are frequently set up to support maintenance personnel in the given zones to eliminate travel time to and from the central stockroom and make standard stock items readily accessible to the craftsmen in the area.

2.6.3. Staffing the Maintenance Department

There has always been a requirement that a maintenance department hires and keeps qualified craftsmen, trainees and supervisors. Increasing labor costs necessitate a constant emphasis on recruiting, selection and hiring. Staffing, however, does not stop with the completion of the hiring process. Compensation, training and performance appraisal are also a part of the staffing function.

Training for maintenance personnel is required to improve the skills of the existing labor force. If equipment complexity increases faster than the technical capability of craftsmen,

the gap will cause a decline in productivity. This gap can be kept closed by additional training of the work force to meet the maintenance requirements of the newer equipment.

Maintenance Staffing Options

This is an area that deserves attention in a maintenance organization. There are four methods that are commonly used to staff the maintenance organization. These are listed below. [4]

1. *Complete in-house staff* is the traditional approach. This is where the craft workers performing the maintenance are direct employees of the company.
2. *Combined in-house/contract staff* where the in-house staff will perform most of the maintenances, but contractors will perform certain maintenance tasks has become a more common approach. Examples of contract staff maintenance are service on air conditioners, equipment rebuilds, or insulation. This method can reduce the amount of staff required for specific skill functions. If the contract personnel are not required full time, this can contribute an added savings.
3. *Contract maintenance staffs* have company supervisors but use contract employees. The contractor is responsible for providing the proper skilled individuals, which removes the burden of training and personnel administration from the company. One disadvantage is not having the same employees all of the time. In this situation some familiarity with the equipment may not be obtained, but the interaction between the in-house supervision and the contract personnel can help to compensate for this unfamiliarity.
4. *Compete contract maintenance staff* includes all craftsmen, planners, and supervisors. The supervision generally will report to plant engineer or plant manager. This eliminates the need for any in-house maintenance personnel. While this program is not yet popular. When coupled with an operator based preventive maintenance program, it can prove to be a cost effective and valid alternative to conventional maintenance organizations.

Determination of Manpower Requirements

The determination of requirements for manpower involves identifying how many people are required and what skills they should possess. The planned use of outside contractors has a direct bearing on the manpower requirements of the internal work force, both with respect to the headcount and the craft skills required. Three basic levels of sophistication are generally found in determining manpower. These are informal, planned and formal methods [3].

i) Informal method

In small maintenance departments involving ten or less craftsmen, informal methods are usually applied in determining manpower requirements. The scope of the operation does not necessitate or usually warrant a lot of effort in developing manpower requirements.

The maintenance manager assigns the work on a day-to-day basis, unless there are unusual circumstances, such as a high level of absence due to sickness or injury. When vacations occur, overtime or more use of relief men generally cover the situation. There is no need for a lot of planning effort. Determining manpower requirements is handled on an informal basis by the maintenance manager himself.

ii) Planned method

In the middle level of sophistication in determining manpower requirements two basic methods are generally used. These are the historical basis and the adjusted historical basis.

The *historical basis* of determining manpower requirements essentially operates on the assumption that what was needed this year is the same as what will be needed in the future. The headcount and skills required for the internal work force are static. The main advantage of this approach is its simplicity. The only planning required is for the replacement of retiring employees and a factor for labor turnover. Other than the need to fill vacancies resulting from retirements or terminations, the requirements remain in a steady state. The main disadvantage to using this approach is a failure to gain any awareness of internal and external factors, which may warrant changes in the requirements of the in-house labor crew.

On the other hand the *adjusted historical basis* method provides for an awareness of change. Although past requirements are used as the base point in determining future needs in the internal work force, the method does provide for changing these requirements in the light of internal and external factors.

iii) Formal method

Formal systems for determining manpower requirements are based on a planned level of effort. They involve fine-tuning manpower planning not only in the light of major internal and external changes, but also specific goals or objectives to be achieved in the coming year.

The formal system of manpower planning requires the determination of the following items:

1. What is to be done and why?
2. Where it is to be done?
3. How it is to be done?
4. When it is to be done?
5. Who is going to do it?

Each of the above items should be performed sequentially. When item 5 is reached (the who is going to do it), the decision to contract or perform in-house must be made.

Because formal system manpower planning is the most sophisticated, it is the most difficult and time-consuming method of determining manpower requirements. Generally, it is mostly used by maintenance departments with high craftsmen, which are large enough to warrant having a planning staff. Automated management information systems are usually employed to facilitate the process. [3]

Training Craftsmen

Training should be mandatory for maintenance personnel as it is one of the ways to increase productivity. Training, that the craftsmen require, are interpersonal skills, the ability to function within teams, problem solving, decision-making, job management performance analysis and improvement, and technical skills. The organization may have today's levels of technology, but maintenance people have yesterday's set of skill. Thus, they must be trained to bridge the gap. Special effort should be given to the people on the staff who deliver the on-job-training. These informal trainers need instruction and buck-up materials in how to teach adults. Technologies are changing, skills must change too.

2.6.4. Establishing Maintenance Control System

The purpose of control is to make sure that people are doing what has been planned. Some maintenance managers find that the easiest way to explain control is to say that it is one side of a coin that has planning on the other side. This explanation may be an oversimplification so far as some academicians are concerned, but the illustration is essentially correct in describing the interrelationship between the two management functions. Plans are meaningless if there is no way to determine the extent and quality of their implementation through controls. Likewise, without goals or plans there are no criteria against which events can be compared for conformance. Plans are expressed in units of measure. Control is facilitated by measuring performance in these same units.

Controlling can help managers to identify mistakes before much damage is done, to coordinate department and minimize waste of efforts, to detect changes before they occur and take action to cope with the changes. Therefore every manager must have means of checking on what is going on and how the whole affair is being conducted.

A Control System

To achieve effective execution of management control for a given task or mission requires a system that contains certain essential elements. These elements are: plans and procedures, measuring, reporting, reviewing, and decision making [4]

Having Plans and Procedures

As previously stated, there can be no control unless there are plans and procedures for what is to be accomplished. Although the type of plan or procedure used will vary according to the task over which control is to be executed, there has to be some concept of what is to be done and the procedures that are to be used in order to accomplish control. Plans define what is to be done, while procedures assign responsibilities within the organization structure for getting the plans accomplished.

Measuring

To determine if plans are being executed properly, it is necessary to have some means of measurement. The most effective means generally rely on some method of quantification. Control is used to measure performance by determining if the tasks are accomplished within the stipulated budget time period and dollar/birr amounts.

Reporting

After developing plans and procedures and methods of measuring performance against plans, the next essential step is to have a reporting system to reveal what is being accomplished. Depending on what activity is being controlled, the reporting method may be verbal, manual (written), or automated.

Reviewing Reported Data

Plans, methods of measurement and reporting methods are of little value unless the performance data is reviewed to identify deviations from the plans. If budgets are being underrun or overrun, or if schedules are not being adhered to, little can be done to rectify the situations unless the specific deviations are identified for management action. The reported data needs to be reviewed to determine where deviations from plans are occurring. Normally, a review of written data is accomplished by staff personnel in the finance or planning and control section of the maintenance department. Regardless of which staff personnel accomplish the task, the detailed written data should be summarized into

meaningful management reports and the specific deviations identified for supervisory action.

Making decisions

Once data has been reviewed to identify deviations from plans, the control function required action on the part of supervisors.

Expenditure rates may have to be adjusted to meet budget requirements. Bottlenecks in schedules may have to be alleviated. In some instances the plans themselves may have to be revised. Plans, as well as control practices, should stay in step with constantly varying conditions.

One of the key elements in decision making is to identify the deviation so the supervisors can do something to alleviate the situation. That is, the deviation should be brought to the attention of that level of supervision that can do something about it, rather than to the maintenance manager or a front-line foreman who does not have the authority to make the necessary changes.

The decision-making process is simpler if supervisors who are to execute the decision participate in determining what action is to be taken. There are three reasons for this participation. First, it will encourage commitment on the part of the participants to execute the decision. Second, it will make possible the pooling of the knowledge of the participants in arriving at a viable decision. Third, it will make all participants aware of the rationale behind the decision [4].

Techniques for Control

There is a wide variety of methods and units of measure which may be used to facilitate control in a maintenance department. The techniques generally are derived to control the dimensions of time or money or both. Some of the most common methods are: Schedules, Budgets, Labor hours, Labor standards, Accounting distribution, and Operations integration [3].

Using Schedules

One aspect of control is the use of time. The statement "finish the job by next Monday" is, in essence, an expressed schedule or plan for completion of work within a specified time period. However reliance on schedules as the only control technique is usually not enough. Additional techniques that would cover the monetary aspect of control were also required.

Using Budgets

The use of budgets as a control technique is a common practice in maintenance departments. Budgetary control involves both cost and time. Costs are expressed in terms of dollars/birr, and the time frame is to be used to control when the expenditures occur. In turn, dollars/birr can be converted to other units of measure techniques, for example, labor hours, headcount, or equivalent heads.

Using Labor Hours

Labor hours are a widely used method of quantifying for measurement. The feedback is usually obtained from time cards which use job numbers to identify the hours expended by each craftsman on specific jobs or projects. The total hours are then compiled for each job by accumulating the hours reported on each time card. The actual accumulated man-hours are then compared to the cost estimate to determine if the job is being completed within the budget.

Using Labor Standards

Perhaps one of the most controversial issues with respect to managing maintenance revolves around the use and types of labor standards for maintenance work. In essence, standards are a measurement method for labor hours. To develop a standard some sort of a feedback as how long it has taken to do a certain type of job is required. Individual estimate, historical average, work sampling, or engineering standards are types of standards that can be used to set the standard. The hours derived from standards are the plan. In turn, the actual hours expended are compared with the planned hours in variance analysis.

In approaching this subject, there are various types of standards that can be used. These are: Individual estimate, Historical average, Work sampling, and Engineered standards

Using Accounting Distribution

Another method of controlling is provided by the way in which the costs of operating a maintenance department are distributed by the accounting system. The two basic methods of accounting measurements are: Service center and Overhead accounting.

When a maintenance department is set up on a complete *service center* basis, all costs incurred by the department are redistributed. The costs of maintaining productive or nonproductive equipment are charged back to the equipment users. Labor is usually charged at an hourly rate for a given craft, that normally includes administrative costs of the maintenance department as well as actual payroll expenses for the craft. Material costs may be charged at actual or may have a handling charge to offset supply room operation costs.

As an *overhead operation*, a maintenance department essentially absorbs all costs against its own budget, and no direct redistribution of the charges is made to its departments. The costs of the maintenance department are collected and applied as part of an overhead rate. The maintenance manager has a direct say in how he will spend his resources since all the money is in his budget. He must establish the priorities in accomplishing work and refuse to perform some work if the expenditures are not covered by his budget.

Using integrating operations

Another method of achieving control is to assure that the various operations for a given activity are properly integrated. In sophisticated forms, this is sometimes referred to as line-of-balance or critical-path planning [3].

CHAPTER 3

Methodology of the Research

In this study both primary and secondary information source is used. Primary source contain raw, original, non-interpreted and unevaluated information. The secondary data sources are technical documents and annual reports that help to cross check the official information and to get details concerning the study. Discussion, interview and questionnaires are techniques that are used for gathering primary information and relevant data for the study.

Data collection is in both qualitative and quantitative nature. Quantitative means anything that exists in a certain quantity and can be measured. The methodology has a quantitative nature because there are quantifiable measures of variables and hypotheses can be formulated, and conclusions drawn from samples to populations. However some of the data are not inherently quantitative that is they do not necessarily have to be expressed in numbers, and so it has also a qualitative nature.

The data required for the study is identified and collected by communicating maintenance staff of selected leather industries in Ethiopia. The basics of all leather industries in Ethiopia, concerning the process, are more or less similar. Thus, samples are taken to generalized where the Ethiopian Leather Industry as a whole stands, concerning the maintenance activity. The sample of leather industries is selected based on the geographical location, and the production capacity of them to take all type from the biggest to the smallest of both the public and private leather industry.

A focused discussion and interviews are held with the respective maintenance personnel of the selected leather industry by visiting them frequently. Questionnaire is also prepared and given for all selected leather industries to have information, which can express the total maintenance activities with in the company. Having the result collected, the culture and the system of maintenance in Ethiopian leather industry can be pointed out.

Based on the maintenance activities like equipment historical recording system, one is chosen among the previously selected leather companies for quantitative data requirement. And then further analysis of maintenance activities including maintenance and equipment unavailability cost is made based on the existing maintenance systems of the company. After analyzing this incorporated cost of maintenance department, the best methods or approach of maintenance will be selected based on background written in literature survey section of the study.

Best method of working to all Ethiopian leather industry is suggested by categorizing the industry in to groups. Daily and yearly production capacity of each leather industry are used to group them. Thus, these companies will have a general model to improve their productivity through effective maintenance management.

Finally, a computer program, which provides any information concerning the maintenance activities, especially equipments historical recording system, the problem of many leather companies, is developed.

CHAPTER 4

Data Collection and Analysis

In this section the data collected from different leather industries is presented and analyzed. After over viewing the whole leather industries in Ethiopia concerning their maintenance section, it focuses only on one leather industry, Ethiopia Tannery Share Company, to take the necessary data and to analyze the problem in detail. Ethiopia Tannery is selected because it has a relatively good implementation of maintenance management system, especially in documentation. Thus, this part comprises two main section; the first deals with the whole leather industries in Ethiopia and the next part focuses on Ethiopia Tannery Share Company.

4.1. Ethiopian Leather Industries

Ethiopia offers a wide range of processed and semi processed hides and skins to the world market. The raw hides produced in the country end up at the traditional/cottage tanning firms and modern tanneries. Of the 20 tanneries, though some are on the process of including hides processing lines, only 8 of them are capable of using hide as raw input. On the other hand 95%, 19 in number, of the tanneries have facilitated for processing sheep and goats skins.

Capacity and capacity utilization of tanneries is determined among other things by: quality and quantity of machinery (embodied technology); production layout i.e. efficient production flow; embodied technology know how; inputs (chemicals, water etc) other than raw hides and skins; labor efficiency; type/nature of raw hides and skins (dry, wet salted etc) and the end products. In Ethiopian tanneries, the capacity utilization is not more than 60% [12]. In most of these tanneries the actual production is very far from the designed as well as the planned capacity due to several reasons. Some of these are:

- Machinery maintenance and related problem
- Price increase of rawhide and skin
- Quality of rawhide and skin

4.1.1. The Data

Currently there are 20 tanneries in Ethiopia that produce leather for the local and export market. The location and capacity of each leather company are listed in the following table.

Name of the Company	Location (region)	Working day in a year	Daily Capacity (pieces)		Yearly Capacity (pieces)	
			Hide	Skin	Hide	Skin
Addis Ababa Tannery	A. A.	259	780	-	202020	-
ELICO	“	250	800	17000	200000	4250000
Dire Tannery	“	280	500	6000	140000	1680000
Wallya Tannery	“	290	300	4000	87000	1160000
Batu Tannery	“	300	400	4000	120000	1200000
Modjo Tannery	Oromia	275	-	8500	-	2337500
Ethiopia Tannery	“	302	1200	10000	362400	3020000
Hafde Tannery	“	300	-	4500	-	1350000
Shewa Tannery	“	280	-	8000	-	2240000
Hora Tannery	“	290	-	4500	-	1305000
Bale Tannery	“	287	300	2000	86100	574000
Kolba Tannery	“	290	-	4500	-	1305000
Tikur Abay Tannery	“	316	-	4500	-	1422000
Bahir Dar Tannery	Amara	300	-	5000	-	1500000
Debre Brihan Tannery	“	300	-	4000	-	1200000
Dessie Tannery	“	280	-	6000	-	1680000
Kombolcha Tannery	“	282	-	4500	-	1269000
Mersa Tannery	“	290	500	10000	145000	2900000
Abay Tannery	“	300	-	3000	-	900000
Sheba Tannery	Tigray	290	-	5000	-	1450000
Total			4780	115000	1342520	32748500

Table 4.1 Capacity and locations of tanneries in Ethiopia

Among these 20 tanneries 8, including the Ethiopian Leather and Leather Product Institute, are surveyed. The companies are Ethiopian Tannery, Addis Ababa Tannery, Batu Tannery, Walia Tannery, Modjo Tannery, Shewa Tannery, Colba Tannery, and Ethiopian Leather and Leather Products institute. Taking these as a sample, the major problems of leather industries in Ethiopia concerning the maintenance activities are evaluated. The table below is the summery of the questionnaires distributed to these industries and my own observation, with the following grade. The questioner, which is distributed to these tanneries, is attached in the Appendix C.

1 – Perfect (Yes) 3 – Fair 5 – Unsuitable or
2 – Good 4 – Poor Nonexistence (No)

No.	Description	1	2	3	4	5
1	Job descriptions are available for maintenance personnel	2				6
2	Maintenance Planners are available					8
3	Maintenance organization effort and attitude		1	2	5	
4	Maintenance shop area location		4	3	1	
5	Maintenance shop area layouts		3	3	2	
6	Maintenance tools/equipment quality and quantity		1	6	1	
7	Supervisory training		2			6
8	Planner/scheduler (or a person who plan) training		1			7
9	General quality and productivity training		2			6
10	Maintenance craftsman training			2		6
11	The quality and skill level of the maintenance work force		1	1	6	
12	The quality and skill level of supervisor group		1	3	3	1
13	Maintenance man-hours are reported to a work order		2	4	1	1
14	Total jobs performed by maintenance are covered by work orders		1	2	3	2
15	The work orders are available for historical data analysis		1	2	3	2
16	The work orders are checked by the supervisor for work quality and completeness	1	1		2	4

17	Planned work orders experiencing no delays due to poor or incomplete plants		1	3	3	
18	The job is completed, the actual time, material downtime, and other information is reported by craftsman	1	2	3	1	
19	Planning the work orders is responsible for dedicated maintenance planner					8
20	The actual time compared with the estimates for monitoring planning effectiveness	1	2	1	2	2
21	The preventive maintenance (PM) program includes lubrication checklists	2	2	2	1	1
22	The PM inspection/task checklist are checked to ensure completeness			1	1	6
23	The plant critical equipment is covered by a PM program		1	1	3	1
24	The PM program is checked against an equipment item's history annually to ensure good coverage		1	1	3	3
25	The frequency of a PM inspection or task/service interval is determined by condition based program	1		4	2	1
26	Controlling maintenance inventory items	1	2	3		2
27	Maximum and minimum levels for the maintenance stores items are specified for the inventory		2	5	1	
28	Different parts are stored in order, so that; it can be easily retrieved	1	2	3	2	

Table 4.2 Evaluations of selected leather industries in Ethiopia

4.1.2. Analyzing Current Situation of Leather Industries in Ethiopia

The current situation of leather industries in Ethiopia is analyzed based on the summarized table 4.2. The following points are seen to be the major problems of leather industries.

- ⇨ The maintenance department of most leather 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. Less than one third of the companies use the work order system properly.

- ⇨ No maintenance department of most leather industry in Ethiopia uses a dedicated planner to plan maintenance activities. But not more than 40% of the organization use planned maintenance done by maintenance head or other staff. Most experts agree that, this is one of the largest potential for cost savings in maintenance area. It is estimated that planned versus breakdown work may have a cost ratio as high as 1:5 [2].

- ⇨ Of all maintenance department of leather industries, almost all are 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.

- ⇨ Another key indicator of the status of maintenance department is overtime compared with the total hour worked. In Ethiopian leather companies overtime is one of the methods used to compensate the workforce required to accomplish the maintenance task. Reducing overtime is essential if a maintenance organization is truly cost effective.

- ⇨ It is known that preventive maintenance is another major part of any successful maintenance program to be productive. For Ethiopian leather industries not more than 10% of them use 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. Over 85% of the companies need major improvement in this area.

- ⇨ 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 not more than one third of the maintenance departments uses the lubrication program properly.

- The other fact related to the preventive maintenance is the lack of coordination between the production and maintenance. In most leather industries, maintenance department given less attention than other department. In these companies production is given priority and surprisingly in some company maintenance is under the production department by repairing the failed machine as the only function. But preventive maintenance should be an organizational policy. On the other hand, in most companies, the problem is communication. Either the maintenance department has not communicated the need for preventive maintenance or the production department is not listening. 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 most leather companies in the country. In some companies they try to overcome maintenance materials problem by using excessive stock. This is a problem because most will not take in to account the inventory carrying costs. But in most companies the minimum order level is not known and so the machines downtime increases due to lack of spare parts.

- The biggest problem in most leather companies is data recording and documentation. Most of them 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. And in some nothing is recorded and documented. 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. While the fact is this, most privet tanneries have no training program for the maintenance personnel at all. For public tanneries there is a training program for supervisors/managers and rarely for workforce.

These are the major problems associated with the maintenance activities of Ethiopian Leather Industry. As can be seen from the above points, almost all leather industries face a big problem on maintenance area. Therefore the maintenance department of all leather industries should be reorganized to alleviate or minimize the above problems. The recommended system will be presented in the next chapter.

As it is stated above, Ethiopia Tannery Share Company has a relatively good maintenance management system, especially in data recordings, than the other tanneries. Thus, even though it cannot represent all leather industries, the following detailed data and analysis is done on the tannery to quantify the problem and to establish the ground to indicate improvement areas.

4.2. Ethiopia Tannery S. Co.

The Ethiopia Tannery Share Company is located at Edjersa, near Lake Koka, approximately 90 km south east of Addis Ababa. The tannery was established in 1975 by the Ethiopian Government, under a technical co-operation agreement with the Czechoslovak Government. The tannery is a multipurpose facility with the capacity to process 17 million square feet of sheep and goat skins annually, and 9 million square feet of cow hide. The principal products of the tannery are:

- Wet blue, crust, shoe uppers, bag leather, hide garments and upholstery from hide
- Pickle, crust, sheep-garment, glove and lining from sheepskin
- Wet blue, crust, shoe upper, sued and lining from goatskin.

Ethiopia Tannery Share Company is one of Ethiopia's largest tannery in terms of production capacity. The tannery has relatively modern equipment and has an operational effluent treatment plant. It is equipped with this equipment to process leather up to finished stage employing 800 permanent and 100 temporary workers. Modern machinery has been installed in the wet-end production section, which enables the tannery to produce finished leather for both the domestic and export markets.

The tannery, with an annual turnover of about Birr 100 million, was transformed into a share company on 1 October 1999. Approximately 80% of Ethiopia Tannery Share Company production is exported in the form of semi-processed and finished leather, in the form of pickled sheep skins, wet blue goat skins, cow crust, sheep garments, sheep gloves, and goat linings. The remaining 20% are sold domestically as finished leather for shoe and garment factories. The company's principal export markets are the United Kingdom, Italy, Romania, Netherlands, Malaysia, Sweden, Germany, France, and South Korea. With a relatively modern technological base the company is equipped for the production of cattle hide, sheep and goat skins up to finishing stage.

4.2.1. Current Status of the Company

The data presented in the section has both qualitative and quantitative nature, and it is used as the input for the analysis part of this section. Before going to the figurative data, let’s see the status of the maintenance department of the company.

4.2.1.1. Organizational Structure of the Maintenance Department

Currently the maintenance department is organized by having three main divisions and one service section. And the maintenance head is directly accountable to the deputy general manager. The organizational structure of the 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 company. 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 company separates the mechanics and electricians in to two groups; for hide section and skin section. Thus the structure is good enough, regarding this problem, to accomplish the task. The organizational structure of the maintenance department is shown in appendix D.

4.2.1.2. 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. Knowing this the company aims to build a new workshop, which makes the shop more comfortable and conducive. Below this the three shops; metal workshop, electric shop, and wood workshop, will be discussed.

Metal workshop

It is the biggest shop among the three. The shop comprises two main operations, welding & sheet metal work, and other mechanical work section, which includes turning, milling and drilling operation. There are three lathe machines in the shop; two of which are heavy-duty lathe. It also consists of milling machine, shaper, hydraulic press, drilling machine, shearing machine, welding machines, and one blade-reconditioning machine. Having these machines the shop is able to process different parts, which can replace the broken or wear items. Besides this operation modification work and other simple machines can be build in the shop. The shop is also staffed by senior machinists, machinists and junior machinists.

Electric shop

This shop is also equipped with different types of machines and tools, which are used to measure signals. Winding is the main operation of the shop. There are instruments to facilitate and test this operation. Tachometer and Ac/dc Ampere voltmeter are also machines, which help to measure different parameters in the shop. Portable measuring set for current, voltage and power, and different types of hand tools are at hand in this shop.

There are senior electricians, electricians, and junior electrician who performs the activities well. The maintenance of electric part of the machines is totally falling on this shop, and actually it should be. But, it is observed that there is some knowledge gap between the worker and the new technology. For example new machines are controlled by PLC (Programmable Logic Controller) and unless training is given concerning this area it is difficult to maintain such machines properly. Frequent training is essential to empower the shop.

Wood workshop

This shop is also very important, as most processing machines especially drums are made of wood. Because of the nature of the tannery processes, that is the process uses different chemicals, wood is selected to build drums and some part of different machines, as it is more resistant than most metals. But as of my observation, the shop is less equipped than expected. It consists of vertical band saw, circular saw, joint plane machine and hand tools. But if there are machines for specific operations, the operation may be facilitated.

4.2.1.3. Maintenance Planning and Controlling System

There is a section, called 'Design, maintenance planning and controlling section', under maintenance department. The maintenance planning should be done by a dedicated maintenance planner staffed in this section. But currently no one is staffed as a maintenance planner, and so the maintenance head himself done the maintenance plan, which lowers the effectiveness of the plan because he may not consider factors for setting preventive maintenance program due to time limit. If there is a dedicated planner, he may work the plan deliberately by considering every factor, to achieve zero breakdowns.

As of my discussion with maintenance staff, the current maintenance plan includes inspections, small & medium preventive maintenance, and overall maintenance having the frequency once in a year based on the condition of the machines. And there are limited resources to perform the prevention action. Thus, the resource limitations influence the

planned maintenance activities not to perform in the given time. In effect, the number of breakdowns jobs increases.

Spare part planning is also one that the company should give more attention. Standard spare parts, special spare parts and consumable spare parts should be identified and work on that to reduce unavailability caused by lack of spare parts.

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.

4.2.1.4. Work Flow of Maintenance

In Ethiopia Tannery Share Company the maintenance activities are performed in two ways; when machine is breakdown that is corrective maintenance and when the work is generates from the 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.

On the other hand preventive maintenance is performed according to the plan. Each section in the maintenance department knows the preventive actions that should be taken within the week. Having the weekly planned sheet, the three maintenance divisions: mechanical; electrical; and utility, wood and civil work divisions assign the supervisory group to accomplish the inspection or other preventive activities. The result reported in similar ways as in the above. The existing workflow of the maintenance department of Ethiopia tannery is shown in the following figures.

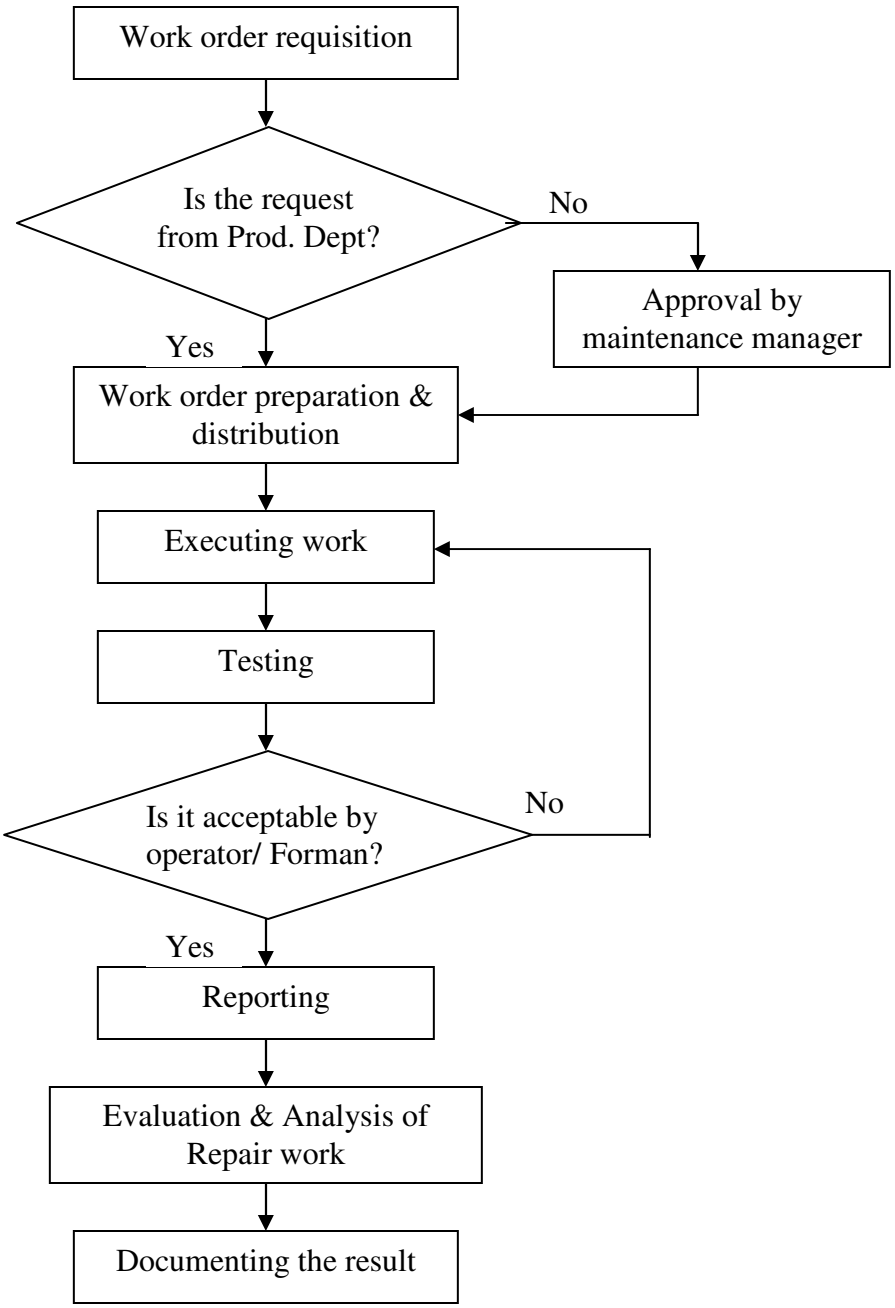

Fig. 4.1 Existing maintenance workflow for breakdown order

For the planned maintenance activity the company has a separate workflow, which is drawn as follow.

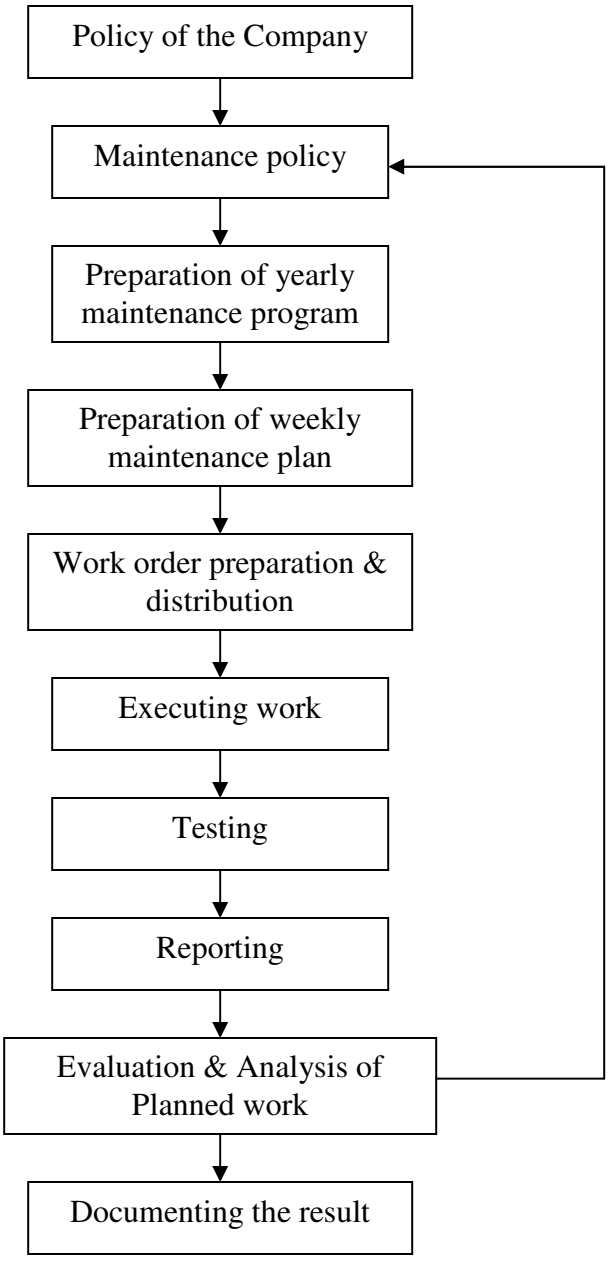

Fig. 4.2 Existing maintenance workflow for planned work

4.2.2. Quantitative Data

The data, presented below, helps to calculate the amount of the maintenance cost and the loss of production due to unplanned maintenance activities. Thus the selected necessary data are:

Total Cost of Production in Ethiopia Tannery Share Company

To produce leather from hide and skin there are costs associated with it. The common production costs for leather industry are raw material cost, chemical 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 1996 E. C. (2003/04) is taken from the annual report of the company and tabulated as follow.

Type of Cost	Cost in Birr
Production cost	132,639,494.60
Operating expense	12,338,195.31
Maintenance cost	2,568,944.29
Total cost	147,546,634.20

Table 4.3 Total costs of the company for 1996 E.C. (2003/04)

With this total production cost, the company makes the net profit of 4,280,270.29 birr in the year. The profit is not only from the net sells of the leather but also from the by-product sales.

Maintenance Cost of Ethiopia Tannery Share Company

Since this study is focused in maintenance, the maintenance cost of the company is selected for the analysis. The maintenance cost of the company is recorded in the annual report as shown below.

Maintenance	Cost in Birr
Employee wage	1249086.05
Spare parts cost	1054199.31
Over time cost	105419.73
Other cost	160238.70
Total	2568944.29

Table 4.4 Maintenance cost of the company in 1996 E.C. (2003/04).

Maintenance Order in Ethiopia Tannery Share Company

The current equipment and machinery maintenance activities of the company consist of both preventive and corrective maintenance. But the corrective maintenance activity highly dominates the preventive activity. The table below, taken from the annual maintenance report of the company, shows that the number of total work order in breakdown, inspection and preventive maintenance, and activities in design and modification work in the maintenance department.

Total number of Breakdown order	6439
Completed	5924
Not completed	515
Total number of Inspection & PM order	1032
Completed	886
Not completed	146
Total number of Design out work	93
Completed	83
Not completed	10

Table 4.5 Total number of order and completed work in 1996 E.C. of maintenance department

Bottleneck Machines and their Availability in Ethiopia Tannery Share Company

The bottle neck machines with their time they spend due to breakdown in the year 1997 E. C. is listed below, which helps to calculate the total amount of money that the company lost due to unavailability of hide and skin processing machines. Thus, bottleneck machines for hide and skin processing are selected and shown in the table as follow.

Machines/Drums	**Qty**	**Planned hrs**	**Downtime in hrs**	**Availability**	
				Actual in hrs	**%**
Liming Drums	12	30390	696.30	29693.7	97.71
Tanning Drums	12	30390	675.20	29714.8	97.78
Splitting machines	2	3920	1025.50	2894.5	73.84
Fleshing machines	2	3920	453.45	3466.55	88.43
Summing machines	3	5880	111.50	5768.5	98.10
Shaving machines	3	5880	1299.1	4580.9	77.91
Setting out machines	3	5250	-	5250	100.00
Vacuum drier	3	5250	-	5250	100.00
Buffing machines	2	11720	142.35	11577.65	98.79
Roller Coating machines	1	1960	74.10	1885.9	96.22
Spraying machines	2	2940	136	2804	95.37
Measuring machines	1	5880	685.40	5194.6	88.34
Total	46	113380	5298.9	108081.1	92.71

Table 4.6 Bottleneck machines of hide section and their downtime due to breakdown in the year

Machines/Drums	Qty	Planned hrs	Downtime in hrs	Availability	
				Actual in hrs	%
Paddles	4	10130	229.1	9900.9	97.74
Liming Drums	7	17730	399.50	17330.5	97.75
Tanning Drums	12	30390	685.25	29704.75	97.75
Fleshing machines	5	9800	1134.30	8665.7	88.43
Summing machines	2	3920	74.45	3845.55	98.10
Shaving machines	3	5880	1372	4508	76.67
Dry Shaving machines	2	3920	913.1	3006.9	76.71
Sum-set machines	1	1960	37	1923	98.11
Toggle Drier	1	1750	-	1750	100.00
Staking machines	5	8760	885	7875	89.90
Spraying machines	2	2940	152.2	2787.8	94.82
Fine flex ironing	1	1750	-	1750	100.00
Total	45	98930	5881.9	93048.1	93

Table 4.7 Bottleneck machines of skin section and their downtime due to breakdown in the year

4.2.3. Data Analysis

The data collected from Ethiopia tannery is analyzed below. Considering the result the next chapter will recommend best maintenance management system.

4.2.3.1. Maintenance Cost Analysis

The common production costs of leather are raw material cost, chemical cost, labor cost and overhead cost. From the table 4.3 the production cost is the lion share of the total cost (about 90%) of the company. And the operating cost, that is the administration, selling and distribution costs are the second larger cost, 8% of the total cost. Maintenance cost is the least of the total cost that is 2% of the total cost. However the hidden cost that comes from lack of proper maintenance is too big. That is, the loss of production due to the unavailability of the machines and the cost associated with this downtime are large. Therefore the maintenance cost is analyzed in detailed in this study. Let's start by considering the maintenance activities done in the company in the year 1996 E. C. (2003/4)

Maintenance Activity

As can be seen from table 4.5, the breakdown maintenance activities is more than six fold of the sum of inspection and preventive maintenance. That means the breakdown work highly dominates, more than 85%, of the total maintenance activity in the year. Which shows that, the existing maintenance planning system of the company cannot decrease the frequent breakdown of the machinery. The reason should be either the plan does not consider factors for interval of inspection, or the planned activities are not well practiced. According to the 1996 E.C. annual maintenance report, 143 activities are performed among the 171 planned activities. Which means around 84% of the planned work is done. So the problem is mostly how they plan the maintenance program. It should be the goal of the department to achieve zero breakdowns. But the main duty of the maintenance department in the company is repairing the failed machine not preventing or inspecting machines. Thus, this situation urges an implementation of a maintenance system, which improves this big number of breakdown. The causes of this failure is analyzed later, now let's see the maintenance cost in the company.

Maintenance Cost

Increasing productivity by looking for ways to reduce maintenance cost is one of the objectives of the study. As it is seen from the table 4.3, the main maintenance cost of the company are employee wage, spare part and overtime. The pie diagram below shows these costs in percentage share.

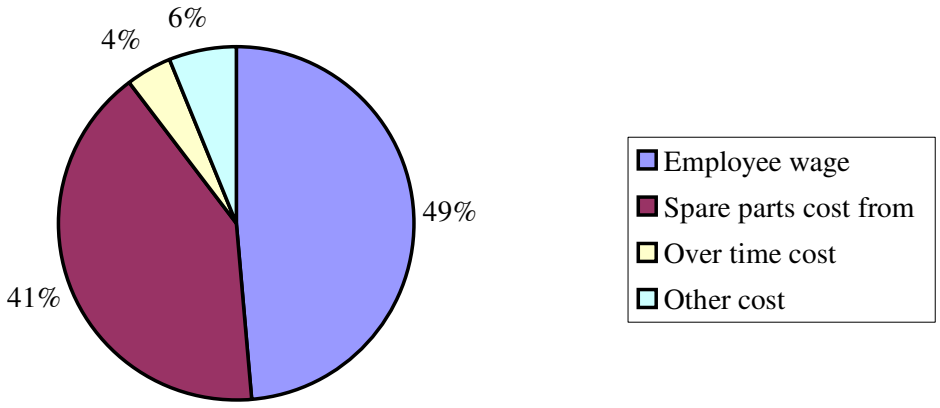

Fig. 4.3 Maintenance cost comparison of the company in 1996 E.C. (2003/04)

As it is shown in the diagram, the lion share of the maintenance cost is the wage of labor and spare part cost. When we consider the wage of the employee, it cannot be minimized, unless we changed the way the department staffed or we use other alternatives of maintenance approach like TPM (Total Productive Maintenance). At present condition the workers have job description for ach of them and work accordingly. The best approach, which has an impact on this cost, is suggested in the next chapter.

The other main cost, which can be minimized, is spare part cost. If the proper maintenance system is applied and if operators are aware about their own machine, the cost incorporated with spare parts decreases dramatically. From table 4.2 it is seen that there are 6439 orders caused by breakdowns. However the total planned order is 1032. This shows us that the company employee spent their time in maintaining the failed machine. The spare part cost can be decrease if the machine properly lubricated and inspected frequently, and if the loosen parts tighten properly before it causes the breakdown of expensive parts etc. The cost of service item (filters, lubricant,…) is normally much less than the cost of breakdown

maintenance. Therefore the spare part cost can be reduced if the preventive activities dominate total work done in the company. Unless the total view of the company changed to preventing the failure before it occurs, it is difficult to make the cost minimum.

Overtime cost is also the one that can be minimized or totally avoided. If we take an ideal condition that it can be totally avoided, if no breakdown occurred and if the crafts are staffed based on the need of preventive maintenance action. Thus, as the number of breakdown jobs decrease, the amounts of overtime will decreases. Therefore, if the amount of overtime is directly proportional to the number of breakdown occurred, the effort should be on decreasing the number of breakdown occurred in the company. How to decrease these breakdowns is the main objective of the study and will be discussed in the next chapter. The analysis below quantifies the loss through the downtime of machines.

4.2.3.2. Downtime Cost Analysis

As Ethiopian Tannery is the biggest and modern tannery in the country, it equipped with different modern machines. These machines are arranged in product layout to process the raw hide and skin to the finished leather. Because of this operationally series arrangement, the breakdown of one machine affects the whole production processes especially for bottleneck machines. Under this title the status of each machine is analyzed to know how much it costs if failed. It is better to analyze the status of the machines by dividing the machines according to the production process flow. The processing plant is classified in to two main sections; the hide and skin section. The hourly capacity and the incorporated money lost due to machine failure of each section will be analyzed as below. Since in the annual report, there was sufficient market in the year 1996E.C., every calculation is made based on this.

1. Machinery for hide process

The hide section of the plant divided in to four sub-sections; beam house, tanning section, re-tanning section, and finishing section. Each section equipped with different processing machines to process the hide. The first three sections dominantly use drums. While the

finishing section uses different types of machines. The general tannery process is shown in Appendix A.

Beam house

Hides should be washed to clean compost and extraneous matter before processing. Hair and excessive flesh should be removed. After removal of hair, excessive lime will be removed. Generally the processes used to perform these operations are: presoaking, soaking, liming & de-liming, fleshing and splitting. Machinery used to accomplishes these processes and the actual hourly capacity of each machine is discussed below. Drums are used to perform presoaking, soaking, and liming operation in this section.

Presoaking Drums

There are four drums used to perform the presoaking operation with the capacity of 2000kg dry weight each. The presoaking operation takes 24hours before it goes to the next operation – soaking. With full capacity each drum is charged 1200 pieces of hide daily. Therefore the number of hide processed in each drum within 24 hour is:

$$The\ actual\ capacity\ of\ \ each\ soaking\ drum = {}^{1200}\!/_{4} = 300 hides / 24 hrs$$

Soaking Drums

Similarly, the presoaked 1200hides are immersed in the four drums for the next 24hrs. The drums are the same as the presoaking drums and so the number of hide processed in each drum per hour is calculated in similar way to be 300hides/24hrs.

Liming & De-liming Drums

In this case also, there are four drums of the same capacity to process the liming operation for the other 24hrs. Thus, the hourly capacity of each drum is similar to those drums, that is 300hids/24hrs.

Here a batch of hide to be processed uses the same drums for all three days, i.e. the same four drums are used for the above mentioned three operations. Thus each drum in this

section used as pre-soaking, soaking and liming drum. Therefore, one can say a drums in the beam house has a capacity of 300hide/ 24hrs

Fleshing Machines

There are two fleshing machine in the beam house, which eliminate the excessive flesh and hair. These two machines should be operated together for 7hrs to finish the daily batch of 1200pieces of hide. Therefore the hourly capacity of each machine is calculated as:

$$The\ actual\ hourly\ capacity\ of\ each\ fleshing\ machine = 1200 \big/ (2 * 7) = 85.71 hides / hr$$

This calculation is done based on the actual operators capacity or based on the current trained of working culture.

Splitting Machine

There are also two machines for the splitting operations. The period of time taken for the 1200pices of fleshed hides is 7hrs. Thus, the number of hide processed in the machine per hour is the same as the fleshing machine capacity 83.71hides.

Thus, in the beam house the hourly capacity of each machine with the associated cost per hour is calculated in the following table. The failure of each machine results to decrease equal number of finished pieces of hide that the machine can produce, if they are a bottleneck machines. Therefore the cost lost in each hour due to the breakdown is calculated using the net profit of the final leather.

In the budget year 1996 E. C. (2003/2004) the company produces 761,314 pieces of hides. The total cost that is the sum of production cost (includes cost of hide, cost of chemicals, direct labor cost, factory overhead cost) and other expenses (general and administration expense, selling and distribution expense) using the cost of production approach is Birr 30,880,488.97. A net sale in the year is Birr 32,489,365.54. Thus the average net profit of one hide leather can be calculated as:

$$The\ average\ net\ profit\ per\ each\ hide = \frac{Total\ sales - Total\ cost}{No\ of\ pieces\ sold}$$

$$= \frac{32{,}489{,}365.54 - 30{,}880{,}488.97}{761{,}314}$$

$$= 2.11 Birr / hide$$

Therefore having the net profit from one piece of hide, the total amount of birr lost due to failure of each machine is summarized as follow. The amount of birr lost per hour is calculated as:

$$Amount\ lost\ birr\ per\ hour = Actual\ capacity * Net\ profit\ per\ each\ leather\ piece$$

Type of machine in beam house	Actual capacity (piece/hr)	Downtime loss (Birr/hr)
Drums in the beam house	300/24	26.38
Fleshing Machine	85.71	180.85
Splitting Machine	85.71	180.85

Table 4.8 Summery of actual capacity and downtime loss in beam house of hide.

Tanning Section

In this section, there are 10 'Investa' drum and 2 'Vallero' drum with a total of 12 drums. The Investa type of drum has a capacity of 2000kg and the Vallero type of drum has a capacity of 3500kg of splitted hide weight. There are also summing, selection, and shaving machine in the section.

Tanning Drums

The Investa and Vellero type of drum together perform a tanning process in 24hrs and an ageing time of 48hrs. Thus, 1200pices of hide can be tanned in one day (24hrs) by charging the four drams at a time. Therefore, the hourly capacity of the tanning drum is the same as those of the beam house dram, 300pieces per 24 hours.

Summing Machine

This machine alone perform its operation in 7hrs to finish 1200pieces of hide. Thus, the hourly capacity of the machine is:

$$The\ actual\ hourly\ capacity\ of\ the\ Summig\ machine = {}^{1200}\!/_{7} = 171.43 hides/hr$$

After this operation selection of the hide is performed manually before it goes to the shaving machine.

Shaving Machine

There are three number of machines which being together to accomplish 1200piece of hide. Therefore the hourly capacity of the machine is

$$The\ actual\ capacity\ of\ each\ Shaving\ machine = {}^{1200}\!/_{(3*7)} = 57.14 hides/hr$$

In this tanning section, all operations are essential to finish the hide to the leather state. Thus taking the above calculated value net profit of each leather and using the same formula the following table is tabulated.

Type of machine	**Actual capacity (piece/hr)**	**Downtime loss (Birr/hr)**
Tanning Drum	300/24	26.38
Summing Machine	171.43	361.72
Shaving Machine	57.14	120.57

Table 4.9 summery of actual capacity and downtime loss, in the tanning of hide.

Re-tanning Section

In this section there are 10 drums, which are required because the weight of the hide decreased by different operation. After the hides are out of the re-tanning drum it should be dried in order to be in a crust form. Thus, summing machine, setting-out machine, vacuum and overhead drier are used to dry the hide. The staking machine then makes it softer.

Finally trimming and selection operations are done manually following the buffing and de-dusting operation.

Re-tanning Drums

All 10 drams have the capacity of 400kg of shaved hide for the 9hrs duration. Here the total capacity of the re-tanning drum is 10*400 = 4000kg. But at the starting 8000kg. was charged in four drums. This shows us that about half of the hide part is eliminated by fleshing, splitting and shaving operation. Since 9hrs is enough to the re-tanning process, all are available in every day. Therefore the hourly capacity of the re-tanning dram is:

$$The\ actual\ capacity\ of\ the\ re\tan nig\ dram = {}^{1200}\!/_{10} = 120 hides / 9hr$$

After this process there is an ageing time of 12hrs, called pilling, in the pit under the drum.

Summing Machine (of re-tanning section)

There are four summing machines used for drying operation. Each of them works for the 7hrs a day to finish all 1200pices of hide. Thus the daily capacity of each summing machine is calculated as:

$$The\ actual\ capacity\ of\ each\ Sum\min g\ Machine = {}^{1200}\!/_{(4*7)} = 42.86 hides / hr$$

Setting-out Machine

The hides are further dried using two Setting-out machine. Both machines take 7hrs to finish all the 1200pieces of hide. Using the same calculation the hourly capacity of the machine is:

$$The\ actual\ capacity\ of\ each\ Settin-out\ Machine = {}^{1200}\!/_{(2*7)} = 85.71 hides / hr$$

Vacuum Dryer

For the drying operation there are also three vacuum dryer machines in the company. Similar to the above two machines they take 7hrs to finish 1200pices of hides in a day. Thus the hourly capacity of one vacuum drier is:

$$Hourly\ Capacity\ of\ each\ Vacuum\ Drier = {}^{1200}\!/_{(3*7)} = 57.14 hides / hr$$

Staking Machine

There are three staking machines available for softening the hides. Three of them being together perform all 1200hides by 7hrs a day. Thus, the hourly capacity of the machine is:

$$Hourly\ Actual\ Capacity\ of\ each\ Staking\ Machine = {1200}/{(3*7)} = 57.14 hides/hr$$

Buffing and De-dusting Machine

Two machines are available for the buffing and de-dusting operation. Both machines being together finished the batch in the working hour of a day, 7hrs. So the hourly capacity of the machine is:

$$Hourly\ Capacity\ of\ each\ Byffing\ \&\ de-dusting\ Machine = {1200}/{(2*7)} = 85.71 hides/hr$$

After this operation trimming and selection operation is done before it goes to the finishing section. In this section dyeing operation is performed according to the customer need. But, since it is not always done and its absence may not affect the total operation, I left the analysis for this particular operation. The following table summarizes the above analysis including the amount of money lost per hour if the machine failed using the above calculated net profit from each hide.

Type of machine	**Actual capacity (piece/hr)**	**Downtime loss (Birr/hr)**
Re-Tanning Drum	120/9	28.13
Summing Machine (for the Re-tanning section)	42.86	90.43
Setting-out Machine	85.71	180.85
Vacuum Dryer Machine	57.14	120.57
Staking Machine	57.14	120.57
Buffing & De-dusting Machine	85.71	180.85

Table 4.10 Summery of actual capacity and downtime loss in re-tanning section of hide.

Finishing Section

In this section the main purpose is to obtain the proper thickness, moisture, lubrication and aesthetic appeal. To make these happen different machines are used. These are curtain coating machine, padding machine, roller coater machine, spray machine and measuring machine. Each machine is analyzed separately below.

Curtain Coating Machine

There is only one machine, which performs the operation in 7hrs of a day. Thus the hourly capacity of the machine is:

$$Hourly\ Actual\ Capacity\ of\ \ Curtaine\ Coating\ Machine = {}^{1200}\!/_{7} = 171.43 hides/hr$$

Padding Machine

Here, there are two machines for the operation. Using 7hrs of a day all hides are processed by the two machines. Thus the actual hourly capacity of the machine is:

$$Hourly\ Actual\ Capacity\ of\ each\ Padding\ Machine = {}^{1200}\!/_{(2*7)} = 85.71 hides/hr$$

Roller Coater Machine

This machine is also a single machine, which alone perform all the hides in 7hrs of a day. Thus the actual hourly capacity of the machine is:

$$Hourly\ Actual\ Capacity\ of\ the\ Roller\ Coater\ Machine = {}^{1200}\!/_{7} = 171.43 hides/hr$$

Spray Machine

There are 2 Spray machines, which used to coat the upper surface of the leather to make the paint permanent. As the roller coater machine it takes 7hr to perform the operation totally. Thus, the actual hourly capacity of the machine is 171.43hides/hr. After this operation thre is an ageing time of 12hrs. Then, after selecting the hides to give the grade operation is done, it goes to the measuring machine.

Measuring Machine

There is only one measuring machine is available for measuring the hide how much square feet it has before issuing it to the final finished product store. This operation is also done in 7hrs of a day. Thus, the hourly capacity of the machine is 171.43hides. After this, Milling operation is done rarely as per the requirement of the customer so the report does not include this operation. All other finishing section machinery capacity with the hourly cost, if it failed, is summarized below. As we state above the net profit per each hide is taken from the calculation we done above.

Type of machine	Actual capacity (piece/hr)	Downtime loss (Birr/hr)
Curtain Coating Machine	171.43	361.72
Padding Machine	85.71	180.85
Roller Coater Machine	171.43	361.72
Spray Machine	171.43	361.72
Measuring Machine	171.43	361.72

Table 4.11 Summery of actual capacity and downtime loss in the fishing section of hide.

2. Machinery for Skin Process

In this section the sheep and goat skins are processed. As stated in the hide section, this section also divided in to four major sections; beam house, tanning section, re-tanning section, and finishing section. Each section equipped with different processing machines to process the skin. Most of the process of skin is similar to the hide one, and so the machines. It started in soaking and ends at ironing machine. Below this the actual hourly capacity of each machines will be calculated for each machine.

Paddles

The paddle in the skin processing section used for soaking operation. There are four drums used for this operation with the capacity of 2100pieces of skin (2700kg.) each. The duration

of this operation is two days (48hrs). Thus, the actual capacity of each paddle is calculated in the same way as in the above.

$$The\ Actual\ Capacity\ of\ \ each\ Paddle = {2100}/{4} = 525 skins / 48 hrs$$

Soaking drum

There is one soaking drum which perform a soaking operation together with the paddles with similar capacity (2100pieces). Thus, the capacity of the soaking machine is the same to be 525skin per 48hrs.

Thus the actual daily capacity of the soaking machines is 10500pieces of skin. Thus, the actual daily capacity of the company is 10500pieces of skin. The amount of money lost by each machine, if it failed, can be calculated in similar way as in the hide section.

The total cost, in 1996 E. C. (2003/04) is Birr 99,566,326.08 for sheep and Birr 17,099,819.17 for goat. Thus the total cost for both skin is Birr 116,666,145.25. The net sale for sheep and goat skin is 99,673,646.08 and 17,258,449.06. And the total net sale of skin is Birr116,932,095.14. In the year, 4,999,728pieces of sheep skins and 1,165905 pieces of goat skins are produced (total skin produced is 6,165,633pieces). Thus, the average net profit per each skin is:

$$The\ average\ net\ \ profit\ \ per\ each\ skin = \frac{Total\ \ sales - Total\ \cos t}{No\ of\ \ pieces\ sold}$$

$$= \frac{116{,}932{,}095.14 - 116{,}666{,}145.25}{6{,}165{,}633}$$

$$= 0.044 Birr / skin$$

Thus, the amount of money lost, if the machine failed is:

$$Amount\ lost\ birr\ \ per\ hour = Actual\ capacity * Net\ \ profit\ \ per\ each\ leather\ \ piece$$

$$= (525/48) * 0.044 = 1.94 Birr / hr$$

Similar calculation is done for all skin processing machines and the tabulated as follow.

Machine type	Operation of the machine	Avg. no. of pieces	Time taken to process (hrs)	No. of m/cs	Hourly capacity (skin/hr)	Downtime loss (birr/hr)
Paddle	Soaking	2100	48	4	525/48	1.94
Drum in the beam house	Liming	2100	24	6	524/48	1.94
Fleshing Machine	Fleshing	2940	7	4	420	18.48
Tanning Drum (Spain)	Pickling & Degreasing	2400	576/24	4	100	4.40
Tanning Drum (Sivit)		1200	576/24	8	50	2.20
Summing Machine	Summing	2100	7	2	150	6.60
Setting-out (sivit)	Setting-out	2240	7	4	80	3.52
Setting-out (aletic)		1400	7	1	200	8.80
Saving (sivit)	Shaving	1400	7	4	50	2.20
Shaving (Alletic)		840	7	1	120	5.28
Re-tanning Drum	Fat liquoring & dyeing	450	9	8	50	2.20
Overhead Drier	Drying	5192	24	2	217	9.55
Staking Machine	Staking	700	7	5	100	4.40
Vertical Staking		350	7	1	50	2.20
Slow Comb. Staking		175	7	4	25	1.10
Extra staking Machine	Extra staking	700	7	1	100	4.40
Toggling	Toggling	1400	7	1	200	8.80
Dry shaving	Shaving	2100	7	2	150	6.60
Spraying	Coating	1000	7	2	71	3.12
Felting Machine	Troming	1500	7	1	215	9.46
Measuring Machine	Measuring	1200	7	1	172	7.57

Table 4.12 The actual hourly capacity and the downtime loss of the skin processing machines

After calculating the downtime cost per hour for each machines, the bottle neck machines should be selected and the time they spend due to breakdown should be listed to calculate the total amount of money that the company lost due to unavailability of processing machines. Thus, bottleneck machines for hide processing machines are selected and shown in the table 4.6 and 4.7. The sum of downtime cost for each machine is then the total loss of the company due to the unavailability of processing machines. The table below demonstrates the total loss for hide processing machines.

Machine/ Drum	**Down time**	**Down time cost/hr.**	**Total downtime cost (Birr)**
Liming Drums	696.30	27	18,800.10
Tanning Drums	675.20	27	18,230.40
Splitting m/cs	1025.50	181	185,615.50
Fleshing m/cs	453.45	181	82,074.45
Summing m/cs	111.50	362	40,363.00
Shaving m/sc	1299.1	121	157,191.10
Buffing m/cs	142.35	181	25,765.35
Roller Coating m/cs	74.10	362	26,824.20
Spraying m/cs	136	362	49,232.00
Measuring m/cs	685.40	362	248,114.80
		Total	852,210.90

Table 4.13 The total downtime cost of the hide processing machines

Similarly, for skin processing machines the total amount of loss due to unavailability of machines is shown below

Machine/ drum	Down time	Down time cost/hr.	Total downtime cost (Birr)
Paddles	229.1	1.94	444.45
Liming Drums	399.50	1.94	775.03
Tanning Drums	685.25	3.3	2,261.33
Fleshing m/cs	1134.30	18.48	20,961.86
Summing m/cs	74.45	6.60	491.37
Shaving m/sc	1372	5.28	7,244.16
Dry Shaving m/cs	913.1	2.2	2,008.82
Sum-set m/cs	37	6.6	244.20
Staking m/cs	885	4.4	3,894.00
Spraying m/cs	152.2	3.12	474.86
		Total	38,800.09

Table 4.14 The total downtime cost of the skin processing machines

The amount of money lost for skin processing machines is much lower than that of hide. This is because in the year the, raw material cost of skin was too high and most of the skin produced for the local market was sold under loss. But, if the figure is put with a comparison of the profit, the loss due to unavailability can be known in percentage of the profit.

The total downtime loss due to breakdown of hide and skin processing machines is 852,210.90 + 38,800.09 = 891,010.99 Birr. And the net profit in the year is 4,280,270.29Birr. Thus, the company's loss in the year 1996 E. C. due to breakdown is:

$$\frac{891{,}010.99}{4{,}280{,}270.29} * 100 = 20.82\% \text{ of the profit}$$

In conclusion, the ultimate profit that the company could have earned through efficient maintenance management can be estimated by adding the net profit within the year and the

cost associated with downtime. Overtime cost is the one that should be added because, as it is seen previously, it is generated from breakdown of machineries. Here the amount of spare part cost is not included since the portion of the cost that is caused due to improper breakdown is not clearly known. So the total amount of money lost in the year 1996 E.C. due to machine breakdown and incorporated cost is more than

$$891.010.99 + 105,419.73 = 996,430.72 \text{ Birr}$$

Taking the ideal condition, that is zero breakdowns, and if the preventive maintenance is performed in a way that doesn't affect the production time, the company could have got an additional profit of:

$$\frac{996,430.72}{4,280,270.29} * 100 = 23.28\%$$

Therefore, 23.28% of the additional profit could have been found in the year if zero breakdown is recorded, and if noting is improved in this year and in the coming years the company will lost 23.28% of the yearly profit. If this is the reality, what are the causes of this breakdown and what should be done to minimize it? The following states the causes and the next chapter explain the remedies that should be taken.

4.2.3.3. Causes of Breakdowns

The above analysis shows that the much work should be done on breakdown to minimize the cost associated with it. 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.

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. So the equipment operators in Ethiopia tannery need to be taught

how to discover abnormalities so they can identify abnormalities early on. In addition to this, the overall working environment of Ethiopia Tannery S. Co. should be studied in order to get the causes of breakdown. Below this the main causes of breakdown are listed.

Condition of equipment

In Ethiopia Tannery S. Co. more than 50% are drums, which most chemical intensive operations are processed. The rest machines are those most mechanical operation taken place. The status of the drums and other machines can be categorized as good, fair and bad condition. New and well-maintained equipment can be categorized under good conditions. Some machines and few drums are classified under this category. Machines, which needs minor repair to be operable but becomes out of operations for short period of time in the year can be classified as fair condition. Most of the machines and some drums are classified under this category. Machines, which require major repair and frequently failed, may be due to age, are grouped under bad condition. Not few machines and drums of the company are categorized under this condition. But the inspection and preventive maintenance schedule in the tannery does not consider these.

There are two types of Drums in the company by driving mechanism, gear driven and pulley driven drums. Gear driven drums are easy to maintain and safe. So pulley driven drums should get more attention and frequent inspection. The other major problem in the drums are leakage through the wooden part, so it should be coated with linseed oil to maintain a perfect humidity of the wood. Moreover most drums and machines are not so clean, which is the cause of most breakdowns by closing some outlets for cooling or other purposes. Sometime it is difficult to detect from where the leakage is, because of dirty machines. It is observed that the limiting switches, gages and other indicators of some machines covers by oils. That can be source of some breakdowns.

Conditions of area around Equipment

Because of the nature of tanneries, the working area around the equipment is wet, especially the beam house and tanning sections. It is not only water, but also some chemicals of the tanning process, which makes the area around the machines wet. It can be one causes of

machine breakdown. Moreover, working floor of the sections are not clean, and useless items are also lying on the floor. This makes workers to de-motivate in their work and allow them to make a mistake, which can be one source of breakdown.

Equipment operators

The operators in Ethiopia Tannery S. Co. are not allowed to do any maintenance activity regarding the machines they are working. Because of this they do not consider breakdowns as their own problems. They frequently make error because they do not know:

- how to perform regular equipment checks.
- when and where to oil, and how much to use for equipments that must be oiled.
- how to replace equipment parts, and perform precision checks.
- how to figure out what is wrong by themselves, if equipment abnormality occurred. Sometimes they simply continue working even if abnormality occurred.

General condition

From my discussion and observation with different maintenance personnel, I understand that craftsman are usually fix the broken part or damaged machine without considering the reason of the occurrence of failure. In effect the machine failed frequently with the same cause of failure. On the other hand, for some machines, it takes a long time to fix minor problems, and often the repair is temporary. Speed of the machine is also one character that affects the production for some of the machines, for example speed of the drums highly affect the quality of the hide or skin. But no one has quantitatively analyzed the loss due to speed.

In conclusion, the causes of breakdown are mostly due to lack of skill in operating, which in turn greatly affects the status of the machineries. These conditions also calls for properly planned and effectively accomplished preventive maintenance in order to reduce machinery down time and hence to increase productivity. Finally the next section elaborate what must be done to do so.

CHAPTER 5

Improvement Areas in Ethiopian Leather Industries

In the previous chapter, the amount of loss due to unavailability of machines, for the case of Ethiopian Tannery, is seen. All of those machines become unavailable due to several reasons of breakdown, which can be eliminated or minimized through good maintenance system as it is discussed in the previous chapter. Thus, the main intention of this chapter is to discuss on improvement areas to minimize breakdown and maintenance cost for leather industries through good maintenance system.

5.1. Equipment Availability Improvement

Breakdowns should be minimized as much as possible in order to meet the planned production amount. The main target of the maintenance department should be zero breakdowns. In order to achieve this the, prevention action should be well organized and coordinated with the other activities.

Every production section of the tannery consists of a particular combination of two components: people (operator) and machine (equipment). No matter how these are combined; one operator per machine or one operator to a number of machines, the workshop system consists of people working closely with machines. For beam house, for example, it is usual to see one operator operating more than one drum. Thus, how the machine is operated, how the machine is kept, and how the working condition is comfortable affect the machine availability greatly, as it is seen in the previous chapter.

Equipment must be changed so it is clean and will not develop abnormalities so easily, and the workplace must be changed so its overall quality is improved. People them selves must be changed so they understand and treat there work, workshop and continually find a new & better way. It is seen that Ethiopia Tannery S. Co. lacks this so each will be discussed below.

5.1.1. Improving the Status of Equipment

To improve the condition of equipment, they must be cleaned, lubricated, checked, and inspected in the planned interval. Cleaning is the most important operation to keep the machine working in a good condition. When machines are cleaned, the outlets become open, and flow becomes ease if the system allows circulation and also protects the fluid from contamination. On the other hand cleaning the machine motivate workers and so they become more productive. Thus, cleaning the machine is an ideal operation to increase the lifetime of the equipment as well as to be productive. For example, the drums in tanneries will have short life unless it cleaned and coated with oily substance.

Cleaning becomes checking; checking becomes discovery of abnormalities. Cleaning equipment requires touching and moving it, coming into closer contact with it, making it easier to tell when it is acting abnormally. That is why "cleaning becomes checking." In fact, cleaning a machine is one of the best ways to check for abnormalities. For example, while cleaning a machine component, one may notice something loose inside.

When cleaning becomes checking, checking in turn becomes a means of discovering abnormalities and dealing with them at an early stage. Thus, when operators learn how to discover abnormalities and practice it, often with the help of maintenance staff, they eventually learn to see their equipment in a whole new way. They learn to use all their senses to better understand the equipment and its condition.

The next step is to understand the abnormalities better that were discovered and come up with ways of restoring or improving them. Then the defective components can be easily repaired, while others can or must be replaced. Perhaps the loose part needs tightening.

Often this is much easier said than done. It may be difficult especially at first, to figure out just what the problem is or how to solve it. But it is only by struggling with challenges and finding a solution that equipment operators come appreciate the issues with which maintenance workers must deal. This experience also helps operators to learn that they cannot be offhand and allow troublesome problems to happen again.

From the viewpoint of the operator, the process of "improving the status of the equipment" involves cultivating a sharp eye for abnormalities, taking the trouble to fix them, and experiencing the pleasure of making successful improvements and finding ways to maintain them.

5.1.2. Improving the Operator's Attitude through Training

Good maintenance management requires operators to understand their equipment. The job related expertise must not be limited to simply operating the equipment; it must also include a lot of things traditionally regarded as maintenance work. All of the equipment operators need to learn how to detect abnormalities. This means acquiring the ability to look at the quality of the product and the performance of the equipment and notice when something is strange. This depends on the following three skills.

- A clear understanding of criteria for judging normal and abnormal conditions (the ability to establish equipment condition)
- Strict enforcement of condition management rules (the ability to maintain equipment condition)
- A quick response to abnormalities (the ability to repair and restore equipment condition)

When an operator has mastered all three skills, he or she will understand the equipment well enough to recognize the causes of future problems and realize, weather the machine is in good condition or not. The following points explain some of the skills that operators should have.

The ability to detect equipment abnormalities and make improvement

- Ability to watch for and discover abnormalities in equipment operation and components.
- Understanding the importance of proper lubrication, including correct lubrication methods and methods for checking lubrication.
- Understanding the importance of cleaning (inspection and proper cleaning methods)

- Understanding the importance of coolant

The ability to understand equipment functions and mechanisms, and the ability to detect causes of abnormality

- Understanding what to look for when checking mechanisms.
- Ability to clean and inspect to maintain equipment performance
- Understanding criteria for judging abnormalities.
- Understanding the relations between specific causes and specific abnormalities.
- Ability to confidently judge when the equipment needs to be shut off.
- Some ability to perform breakdown diagnosis

The ability to understand the relationship between equipment and quality, and the ability to predict problems in quality and detect their causes.

- Ability to analyze problem related phenomena
- Understanding the relationship between characteristics of quality and the equipment. For example, for the case of shaving machine stop production, if the leather does not have uniform thickness.
- Understanding casual factors behind defect.

The ability to make repair

- Ability to repair parts
- Understanding the life expectancy of parts
- Ability to deduce causes of breakdowns
- Ability to take emergency measures
- Ability to assist in overhauls repairs

This is actually the concept of Total Productivity Maintenance, which takes the operators as a key player in equipment availability. On the contrary, the operators in Ethiopia tannery are not totally aware of these things, as it is discussed in the previous chapter. It is stated that operating the machine is the only responsibility of operators. This system makes the

machines to fail frequently because operators are not responsible for the machines they operate.

In Ethiopia Tannery the general thinking among equipment operators is ‘ I run it, you fix it’. Operators consider themselves responsible only for setting up unprocessed hide or skin. Any maintenance activities including light maintenance and lubrication are the responsibility of the maintenance staff. This way of thinking makes the operators not to care about the machine.

The operators can prevent the breakdown simply by getting a feel for abnormalities through physical contact with the equipment. Taking time to tighten loosen bolt, lubricating dry parts and cleaning away dirt, they can increase the life of equipment. Therefore, training the operators of Ethiopian tanneries increases the availability of equipments that helps to maximize the productivity.

5.1.3. Improving the Overall Quality of the Workplace

Once operators have developed a sharp eye for abnormalities, they start to think what must be done to minimize the causes of abnormality. They can, then, focus on everything around it, tools, processing conditions, control systems, and so on. These peripheral aspects of the workplace are also covered with abnormalities, and having seen them, the operators know that timely action must be taken to prevent them from developing into big problems. So the first step to changing the workplace is taken when operators begin to notice and list the countless things that need improvement.

In making improvements, the completion of each step brings to a new step with new problems. For example, suppose it is discovered that the production rate of hides or skins needs to be accelerated in the tannery. This itself creates a new set of problems. To deal with them, it is necessary to figure out what can be done by the workers, what must be handled by the technical staff, and how the solution should be carried out.

Changing the way of seeing and thinking about things

To change the workplace there must be a change in the way of thinking about it and everything in it. With current attitude of Ethiopia tannery, there is no recognition of the abnormalities and defects that exist in the machines and tools that are used. For example, as it is stated above, the speed of the drum affects the quality of the leather produced. It may occur by the slippage of belts for belt driven drums. But most operators either do not notice it or do not feel the need to do anything about it. Thus operators need to concerned about the overall quality of workplace, good or bad, is entirely the result of human behavior. So the most important idea that workers should cultivate is an abnormalities before they develop in to major problems.

Seeing each breakdown as a humiliation

It is all too easy to find workshops of the tannery where the operators to look at breakdowns as someone else's fault: blame is usually put on the maintenance staff. This is a big problem. Availability of machine improvement will not go anywhere until equipment operators and/or other workers take responsibility for their workplace, regarding every breakdown as a sham. Taking responsibility means taking action. When breakdown occurs, the operator concerned should meet with a maintenance worker to fined out exactly what he or she did that caused it or could have done to prevent it.

In summary, changing the equipment leads to changing attitudes and behaviors, which in turns leads to improving the overall quality of the workplace. These three changes - in the equipment, the people, and the workplace - are basics for improvement of availability of equipments.

5.2. Developing Effective Maintenance System

Planned maintence is essential for efficient maintenance activities. In Ethiopia Tannery Share Company there is a planned maintenance activities but it covers less than 15% of the total work order in the year 1996 E.C. The maintenance staff said that they are following condition based maintenance system. That means every planned maintenance activities are programmed and done after the inspection is executed. However their yearly maintenance

plan shows that, they are following the fixed time planned maintenance system also. One of the other big problems in performing planned maintenance activity is that the maintenance plane does not consider the production plans. Thus several conflicts between maintenance and production staff are observed. The maintenance plan should be done considering the production plan of the company to avoid such conflict and to perform the planned maintenance activity.

Therefore good managerial actions must be taken to manage the total maintenance activities done in the company. Maintenance managerial activities that help for the construction of maintenance workflow model are listed below.

5.2.1. Inspection Management

Inspection is the examination of certain critical machines or parts of equipment or machines to determine their state or condition. This information is useful for planning and programming actions, which help to maintain accuracy of the machine and the prevention of unwarranted breakdowns of the tannery.

A sudden failure rarely takes place, as there are always signs of gradual wear and tear noticeable long before an actual failure occurs. Periodic inspection helps to detect extent of deterioration and plan for its repair or rectification, or if need be, even make replacement before an actual breakdown occur. It is therefore, a means of reducing breakdowns and loss of production, and the cost of expensive repairs and many other expenses. In Ethiopia tannery, actually, the inspection is done but it cannot prevent the machine from frequent failure. The problem is either the inspector does not understand the purpose of inspection or he/she may not know what to inspect. Thus, the inspection intervals should consider some factors as follow and the check sheet should be at hand whenever inspection is takes place.

Frequency of Inspection

To determine the frequency of the inspection in Ethiopia Tannery S. Co., the following engineering analysis should be considered

- the age of the machine, its condition and value
- severity and intensity of service
- hours of utilization, are they prolonged or intermittent
- susceptibility to wear and tear – is the machine subjected to dirt, friction, fatigue, stress, corrosion?
- susceptibility to damage – is the machine subjected to severe vibration, overloading, abuse, heat, freezing cold?
- susceptibility to losing adjustment during use – will the maladjustment or non-alignment affect the accuracy or functioning? Will the lack of proper balancing affect performance?
- safety requirements and considerations

Inspection Checklists

Every machines in the Ethiopian tanneries needs daily, weekly, and monthly inspection check sheet. Daily inspection are performed to insure that, critical equipments are in a good condition so as to continue to perform satisfactorily, and that no such situation develops, which might cause a failure or breakdown suddenly. In the same procedure weekly, monthly and annual inspection should be done. The inspection routine in Ethiopian tanneries would involve carrying out checks for:

- any abnormality vibrations, or any abnormal noise
- the temperature of all bearings to ascertain that they are acceptable levels and that they are not overheating condition
- leakages from the gland and gauge to see weather they are excessive
- oil level in cups
- grease nipples to insure that they are not dry

The list of operation below shows what to perform daily and weekly as an example for one of the leather processing machine – splitting machine.

- Daily maintenance action for splitting machine
  - Thoroughly clean the machines
  - Check the safety barrier, pedals and emergency stops for function
  - Lubricate at all points specified by the manufacturer and replace all damaged grease fittings
  - Check the blade oil tank and add oil as required
  - Clean the scrapers and blade-cleaners
  - Clean the grinder covers

- Weekly maintenance action for splitting machine
  - Lubricate all the points specified by the manufacturer and replace all damaged or none functioning grease
  - Check all the hydraulic and manometer Pressures and the oil level (fill as required)
  - Clean and lubricate all transmission chains
  - Adjust the transmission chain tension and check the tensioners
  - Check all the transmission belts, adjust the tension and check the tensioner
  - Check the blade width
  - Check the grinder diameter
  - Check the blade double face shape and correct it if necessary
  - Check the play between the blade and grip plate guide plates and adjust as required

Therefore in Ethiopian tanneries the inspection operation should be managed well because it is a base to decide whether the equipment needs a small or overhaul preventive maintenance, or not.

5.2.2. Spare Parts Management

This means organizing spare parts so the right ones are always in the right place at the right time. The stoking system should be well designed or organized to facilitate the supply of spare parts to decrease the delay in retrieval of the required item. The spare part cost is also the one, which should be considered. It is the second main cost of the maintenance

department following the employee wage. Most spare part ordering is taken place in an urgent way because the machines are waiting for parts to be available. This is the main reason for the maintenance cost increment in Ethiopia Tannery S. Co.

In Ethiopia Tannery the spare parts for each machine should be categorized and listed as consumable, standard, and special spare parts. This helps the maintenance department to order which type of spare part at what time. It also helps to know which are used in common for different machines.

The spare parts are mainly purchased from the local and foreign market. Few are worked in the metal and wood workshops of the company. The main function of these shops are reconditioning blades and other damaged parts, and some modification work.

5.2.3. Work Management

The work done in maintenance department of leather industry should be well managed to be productive. In Ethiopia Tannery S. Co. the resources are limited and so they should be assigned in a systematic way to do all the maintenance works in the given period of time. It is a practice of the Ethiopia Tannery S. Co. to pass the preventive maintenance if the workers are occupied by corrective maintenance activity. But it is known that the preventive maintenance is very essential and should be performed according to the planned time to avoid or minimize the corrective maintenance. Therefore, since the works are generated from two sources, from the planed and from the breakdown, they should be managed based on the resources available.

To perform these two maintenance activities, the production and maintenance manager should have a common understanding concerning these activities. In Ethiopia Tannery S. Co. production department is don't allow any interruption during the production time to achieve planned production. So maintenance craftsman can not get time for preventive maintenance during the production time. Thus, the production manager should be cooperative and should understand the prevention activity to manage the planned work easily. The maintenance program should also consider the production plan during the plan.

5.2.4. Equipment Failure Management

Whenever equipment breakdown occur in Ethiopia Tannery S. Co., the time required for repairing it is too long. That affects productivity, because, unless the machines are repaired, no product is produced. Thus the main activity of failure management is to shorten the repair time.

In Ethiopia Tannery S. Co., usually, much of the time between the occurrence of the breakdown and completion of the repair is spent by diagnosing the causes of failure or by looking for the broken part or parts. Thus maintenance people should be trained on how they diagnose and understand the work. Having the diagnostic device may be expensive for maintenance department, but the maintenance staff should work on inventing themselves to suit their particular situation. On the other hand spare part management is also one factor to shorten the repair time and it is discussed above.

Therefore, these four managerial functions are basic to develop a successful maintenance workflow. The procedures in which all maintenance activities should be clearly identified and known by all concerned bodies of the tannery's staff. Thus the duty and responsibility of production and maintenance managers, supervisors, planner, operators, and the craftsman should be clearly identified and known by the company's concerned department.

As it is seen from section four (Fig. 4.2 and 4.3) the workflow of the existing maintenance department of Ethiopia Tannery S. Co., several problems can be extracted. The work is not planned to consider the preventive and the corrective action together, so lack of coordination between the two work flow is observed. And also the spare parts are not ordered at the work planning stage, thus the downtime of the machine increases by waiting the spare part. Actually, this is not seen in the existing flowchart, but from their practice it is observed that the spare part order is at executing stage.

Therefore, the workflow should be modified to alleviate the above stated problems. Thus, the modified workflow, which considers the above problem, is proposed below.

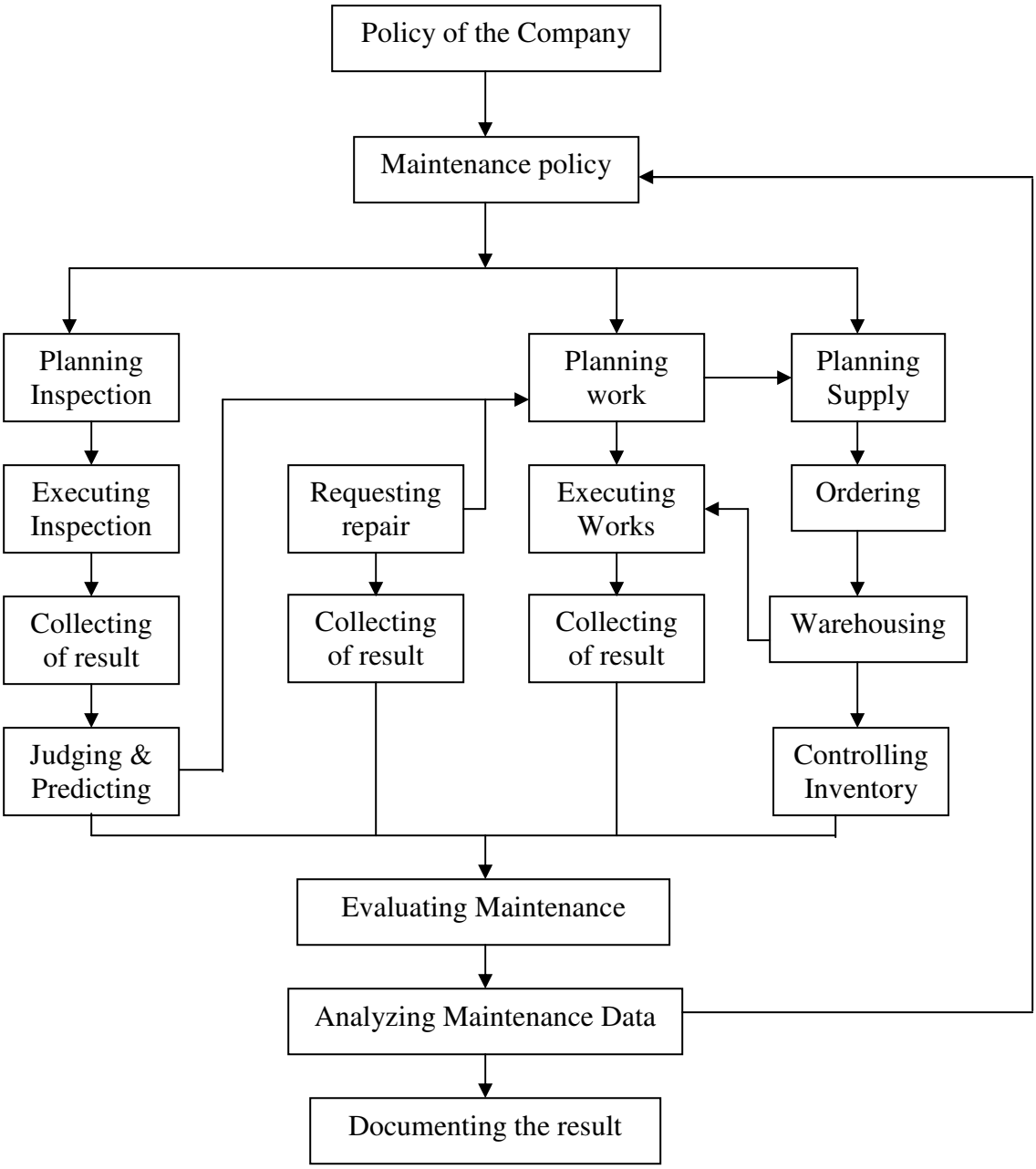

Fig. 5.1 The proposed maintenance workflow

The model proposed above has many advantages over the existing maintenance workflow of Ethiopia Tannery described previously. It is seen that Ethiopia Tannery uses fixed time maintenance management system. That means the machines are maintained according to the maintenance program planned once in a year. But the very nature of production in tanneries is continuous, that is hide or skin is perishable unless continually processed, and

varies with time, which calls for condition based maintenance system. It is most efficient interims of cost and availability. This model uses condition based maintenance type for these reasons. Daily, weekly and monthly inspections are planned for each machines then inspection will be executed accordingly. Having the result the condition of the machine is known and so the need of overhaul, medium or small maintenance or not will be decided. Then after the work will be planned taking this as a feedback with the requisition of failed machine together. Thus when the work is planned it considers both the preventive and corrective activities together. While planning the work the type and amount of spare parts needed will be ordered simultaneously. This decreases the time spent in waiting the spare parts.

The result collected from each step will be evaluated and analyzed to be a feed back for the next year maintenance policy preparation and documented finally.

The model is can be applied for all leather industries in Ethiopia. Because it consists of basic duties that must be performed to minimize the breakdown of machines as well as the maintenance cost. But the difference in Ethiopian leather industries is the capacity, which come from the number of machines each company has. Therefore, how it should be done and who is going to do the work is the difference and it is discussed below by categorizing them in to groups.

5.3. Working Method for Leather Industries in Ethiopia

There are 20 tanneries in Ethiopia, which provide the products to local and external marker. Most of them are concentrated around 100km radius of Addis Ababa. Out of these tanneries, 4 of them are public tanneries; namely Addis Ababa Tannery, Ethiopia Tannery, Modjo Tannery and Kombolcha Tannery. The rest are private tanneries. The general status of Ethiopian leather industry is discussed in section five and their list is found in table 4.1.

These tanneries can be divided in to three section based on the capacity they produce and the type of products they produce, hides or skins. Because the labor cost, overhead cost, sales volume, maintenance cost and the number of workforce are directly proportional to

the capacity of the company. Machines for hide production are bigger in size than that of skin. So the category also considers this because they need more time and labor. A, B, and C are the name given to the group.

Tanneries which have a capacity to produce 500 and more pieces of hide, and 10000 and more pieces of skin per day is categorized under the A group. Tanneries, which produce hide above 300pieces regardless of the skin product is under B group. And the rest that produce only skin are grouped under C group. Using table 4.1, which shows the capacity and location of each leather industry, the following tables are generated.

Tanneries that are grouped under A are listed in the following table.

Name of the company	**Daily Capacity (pieces)**		**Yearly Capacity (pieces)**	
	Hide	**Skin**	**Hide**	**Skin**
Ethiopia Tannery	1200	10000	362400	3020000
ELICO	800	17000	200000	4250000
Mersa Tannery	500	10000	145000	2900000

Table 5.1 List of tanneries under group A

Group B tanneries are also selected using the mentioned method and listed in the following tables. Here Addis Ababa Tannery is the only tannery, which produce leather from the hide only. Others produce both in a medium range.

Name of the company	Daily Capacity (pieces)		Yearly Capacity (pieces)	
	Hide	Skin	Hide	Skin
Addis Ababa Tannery	780	-	202020	-
Dire Tannery	500	6000	140000	1680000
Wallya Tannery	300	4000	87000	1160000
Batu Tannery	400	4000	120000	1200000
Bale Tannery	300	2000	86100	574000

Table 5.2 List of tanneries under group B

Group C tanneries are relatively small in capacity but bigger in number, 12 tanneries, and manufacture finished or semi processed skin leather from goats and sheep only.

Name of the company	Daily Capacity (pieces)		Yearly Capacity (pieces)	
	Hide	Skin	Hide	Skin
Modjo Tannery	-	8500	-	2337500
Hafde Tannery	-	4500	-	1350000
Shewa Tannery	-	8000	-	2240000
Hora Tannery	-	4500	-	1305000
Kolba Tannery	-	4500	-	1305000
Tikur Abay Tannery	-	4500	-	1422000
Bahir Dar Tannery	-	5000	-	1500000
Debre Brihan Tannery	-	4000	-	1200000
Dessie Tannery	-	6000	-	1680000
Kombolcha Tannery	-	4500	-	1269000
Abay Tannery	-	3000	-	900000
Sheba Tannery	-	5000	-	1450000

Table 5.3 List of tanneries under group C

Group A Tanneries

These tanneries are bigger in size and so they have a number of processing machines. The number of maintenance staff is also large accordingly. Currently, complete in house staffing method is used in Ethiopia tannery. Even though this method is a traditional one, group A tanneries should use this method because there is no company in Ethiopia which gives maintenance service in organized manner. Actually there is no need to have a maintenance personnel for utilities like maintaining fans, waste treatment plant or others equipment which has no direct relation with production process, if there is a well organized service giving company on maintenance activity. Since no company is giving this service, these companies have to use this complete in house staffing method to support their own company as well as others like group B and C companies. To make it cost effective, the department should take supporting group A and B as one means of income generation. Since tanneries in Ethiopia has similar working processes and so the equipment, this group can take this opportunity to strengthen the maintenance department both in human resources and in working instruments & tools. The maintenance organizational structure should account this service, as it is beneficial for the company. By this the productivity of all leather industries can be increases.

Group B Companies

This group has medium capacity in production of leather from hide and skin. Basically the type of machine used here are similar with group A. the number of machine is a basic difference. Thus, the main difference between this group and that of group A is the staffing method, as it is stated.

Since the number of machine they have differs, the number of workforce required is different. Unlike group A, if this group uses a combined in-house/contract staffing method, they will be cost effective. The in-house staff will perform most of the maintenances work, but contractors will do certain maintenance tasks, which have no direct relationship with the process. This system has become a more common approach, in developed countries because there are well-organized companies that provide maintenance service on specific areas. Here also, if group A tanneries are well organized as a complete in house method of

staffing and if they are willing to give this service, this group do not need staffing or training this personnel on the area. They just contract the staff required for the work outside from those companies. Some of the maintenance works that can be done by contract staff, for this group, are; service on waste treatment plant, air conditioners, equipment rebuilds, or installation.

The method can reduce the amount of staff required for specific skill functions. If the contract personnel are not required full time, this can contribute an added savings.

Group C Companies

These are small tanneries and most of them exports in semi processed state. Though the number of machines in these tanneries are small, each should have an inspection plan, work plan and spare parts plan to assure the availability of them. Thus, this group should strictly use the developed system above.

The number of manpower required in this group is low when it compared to other groups. Here operators should play a major role in maintenance work. Daily inspection and some of the weekly inspection can be done by operators, and the rest inspections work can be performed by mechanics. Partial and full overhaul preventive maintenance action can be worked by outside contractors. Therefore, *Contract maintenance staffing* method may be used for this group. This method has a company supervisors but the rest are contract employees. The contractor is responsible for providing the proper skilled individuals, which removes the burden of training and personnel administration from the company. One disadvantage is not having the same employees all of the time. In this situation some familiarity with the equipment may not be obtained, but the interaction between the in-house supervision and the contract personnel can help to compensate for this unfamiliarity.

Therefore, if all the three groups use the working method as stated, they will benefit in cost savings and so the productivity of the leather industries in general increases. But the method stated above highly needs the coordination of companies. There must be good communication between them, as it benefits all.

5.4 Computer Program for Maintenance Management

The current maintenance management system of Ethiopian leather industries with a recommended system is seen previously. But, if the system is automated, it will be more efficient. Productivity of maintenance department can be improved through this computer program. Because the plan becomes effective if it gets sufficient feedback form the previous analyzed maintenance activities. This is the problem of most leather industries in Ethiopia, as it is explained in the introduction section. Moreover the program helps the leather industries 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 the leather industries. The program has six entity menus. It is user friendly and if any difficulty the help menu gives how to use the program. Below, each of these entity menu is discussed in brief.

The first entity menu is employ menu. This helps to enter the information about the employee, who is doing or going to do the work. Thus, the necessary information concerning the employee will be recorded and so the planner or the supervisor can easily understand who is capable to assign the work. This menu also contains the search bar by the name or identification number of the employee to get the detailed information concerning the employee. The figure below shows the interface of the employee menu of the program

Fig. 5.2 The employee menu of the program

The second entity is equipment menu. This menu contains all the necessary data concerning the machine in the company. Here, the type, the model, the year manufactured, and the capacity 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. The figure below shows the interface of the equipment menu of the program

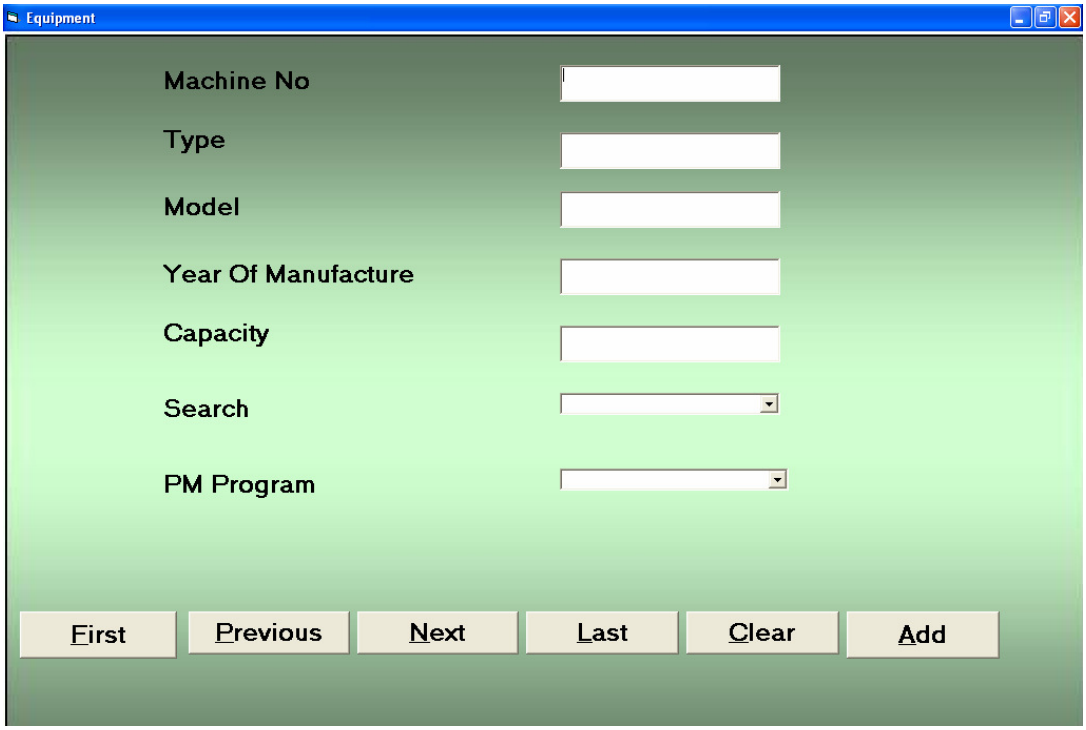

Fig. 5.3 The equipment menu of the program

The next menu is the requisition menu, which helps to record the persons who request the work and approve the work. The compliant bare in this menu record all the compliant that the requester wants to be performed. It also contains the bar for the entity of the name of operator, who was operating the machine before it failed. Thus the performance of the operator can be easily known by the manager to provide the training or other purpose. Requisition number is used here for searching purpose. The figure below shows the interface of the requisition menu of the program

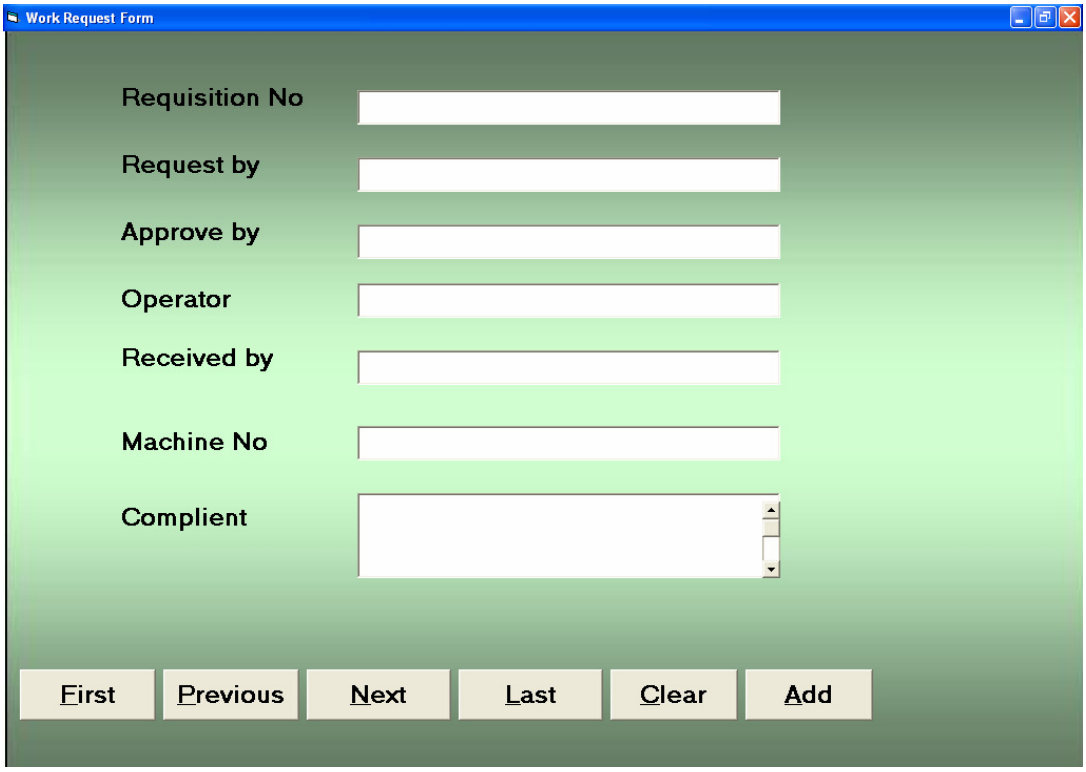

Fig. 5.4 The requisition menu of the program

Activity menu is the forth entity menu that helps to record all activities concerning the machine under maintenance. In this menu; type of maintenance, description of work, findings, time taken with start and finished time will be recorded. The downtime of the machine due to what type of maintenance, that is inspection, small or medium preventive, overhaul, predictive, lubrication… can be recorded. Moreover it contains the information about what parts are replaced during the activity and who is assigned as a leader and who are helpers in accomplishing the work. Thus, it has very important information for the downtime cost analysis. Job order number is a code used to search in this menu. The figure below shows the interface of the activity menu of the program

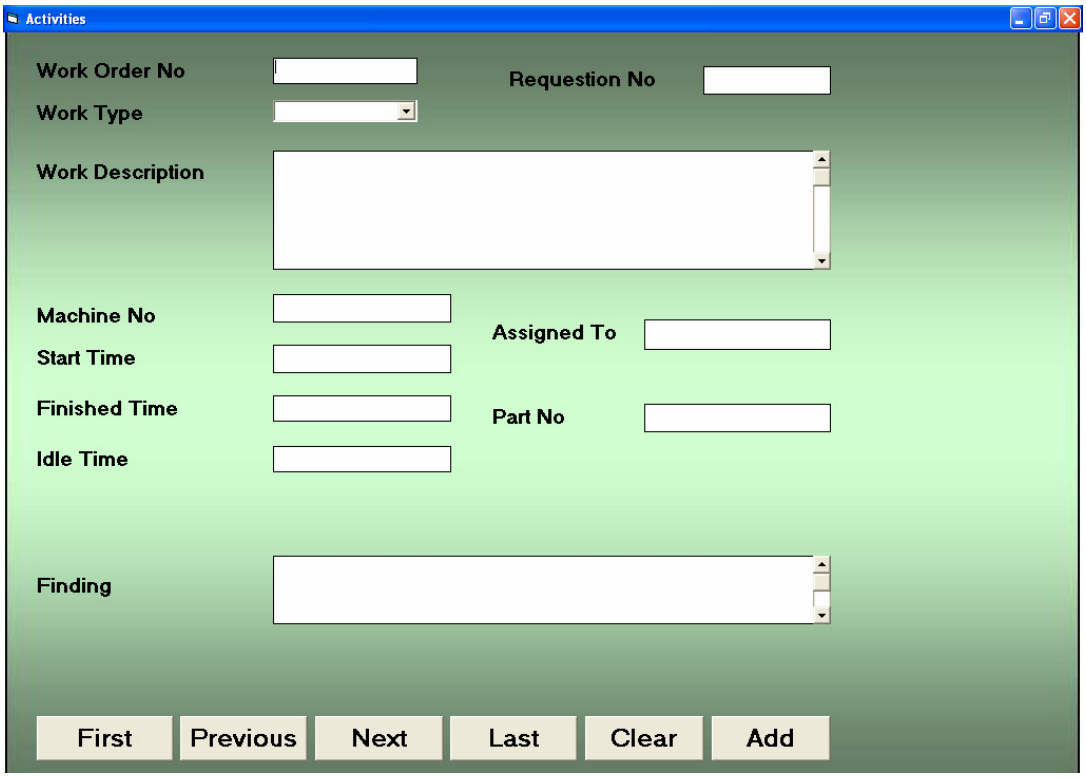

Fig. 5.5 The activity menu of the program

The fifth menu is parts menu. This menu helps to record the information about the parts, which are going to be replaced. It has the entity bars for the number and type of spare parts changed with their price. Thus, what types of parts are frequently changed will be easily analyzed. The figure below shows the interface of the parts menu of the program

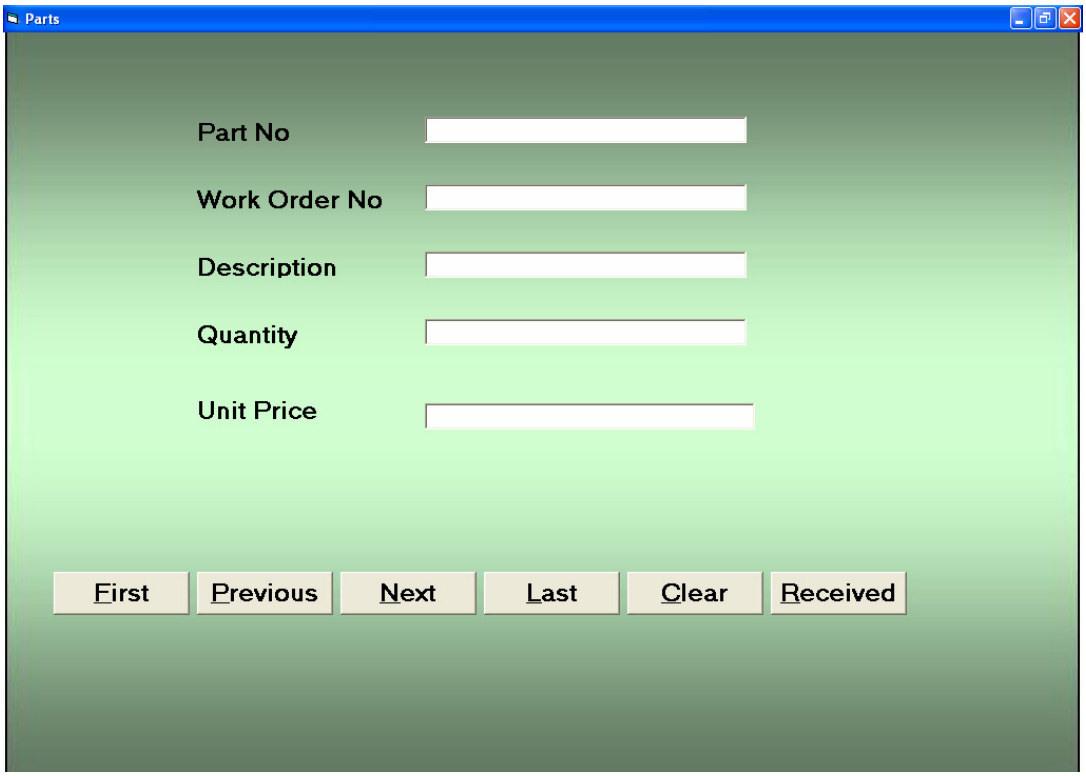

Fig 5.6 The parts menu of the program

The last entity menu is the department menu that helps to record all sections in the company with their code. This menu is created to know the section or department code, which is used in the other menus. Other menu in this program used only the code of the sections that the maintenance activity is performed. The figure below shows the interface of the department menu of the program

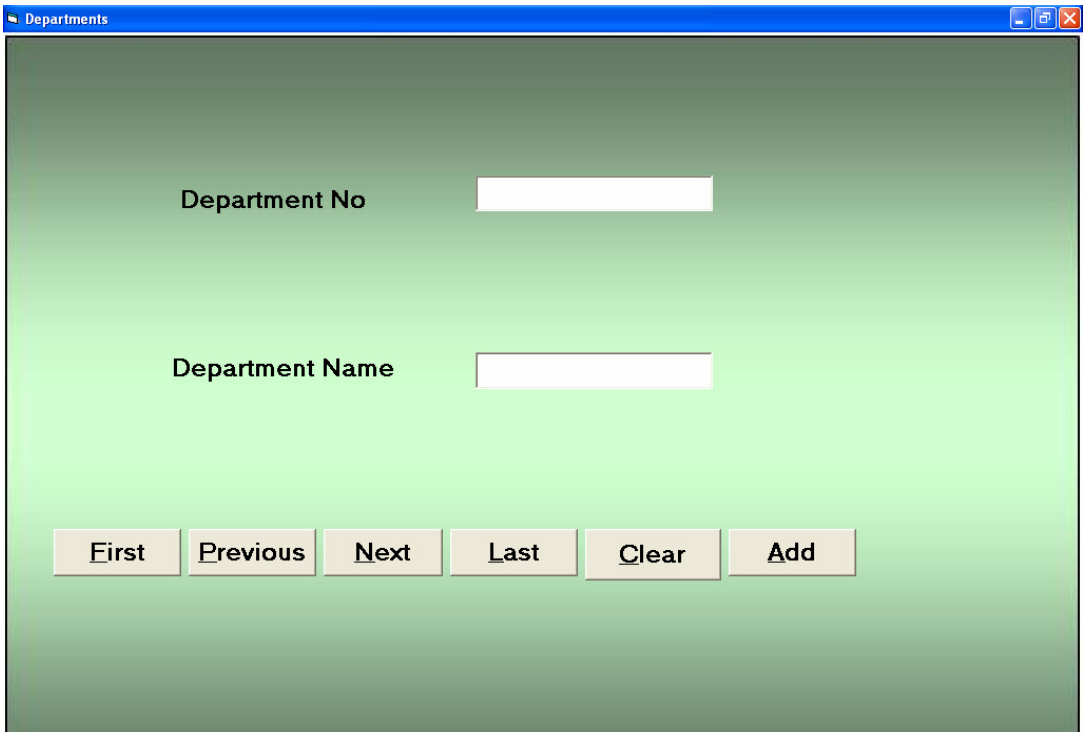

Fig. 5.7 The department menu of the program

CHAPTER 6

Conclusion and Recommendation

6.1. Conclusion

Based on the findings in the previous sections, equipment maintenance system of most leather industries in Ethiopia needs much improvement. Maintenance department of these industries 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 most of leather industries in Ethiopia.

In this paper Ethiopia Tannery Share Company is taken as source and reference for the case study. It is seen that most of the work order, in this company, is generated from breakdown of machines. Which shows most of the maintenance activities are corrective action rather than preventive. In effect, the downtime of the machines rises. These downtime of the machines costs the company around one million birr loss of production in budget year of 1996 E.C., that is approximately one forth of the total profit gained in the year. Thus, this paper finds out the causes of breakdown and ways to minimize them in order to increase the machines availability.

The main causes of breakdowns investigated in the paper for Ethiopia tannery are condition of equipment, operators, and condition of the area around the equipment. Thus, equipment must be changed so it is clean and will not develop abnormalities so easily, and the workplace must be changed so its overall quality is improved. People themselves must be changed so they understand and treat their work, workshop and continually find a new & better way.

As it is the main objective, this paper proposed a model for the workflow system of maintenance management system, considering the existing problem. The model simplifies the whole process and makes the activities to be efficient. So the productivity will be improved. It is developed by coordinating the four major duties of maintenance; inspection

management, failure management, work management, and spare part management. 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.

This study also categorizes the 20 tanneries in to 3 groups based on the production capacity as A, B & C to suggest a best method of handling maintenance activities for each group. The maintenance workflow model developed in this paper is applicable for all type, the difference is only how and who is going to do the task. And so how each group should handle the task is seen in the paper.

6.2. Recommendation

The following recommendations are proposed for all leather industries in Ethiopia based on the outcome of the paper.

1. Maintenance should be an organizational policy as one of the strategy in being productive and competitive. And the department should be given emphasis, as it is one of the main areas for productivity improvement. The developed maintenance workflow system in this paper is recommended for them to be effective.

2. Maintenance awareness and commitment should be created in the companies starting from the top management in the organizations up to the lower level through training and seminars.

3. Companies should encourage their operator to become familiar with the machines they operate. Training should be provided for them to acquire:
    - The ability to detect equipment abnormalities and make improvement,
    - The ability to understand equipment functions and mechanisms, and the ability to detect causes of abnormality
    - The ability to understand the relationship between equipment and quality

- The ability to make repair

4. Equipment operator should be responsible for machine and the workplace by taking every breakdown as a shame. Taking responsibility means taking action. When breakdown occurs, the operator concerned should meet with a maintenance worker to fined out exactly what he or she did that caused it or could have done to prevent it.

5. The equipments should be kept so clean because most of the abnormality develops from dirty machines and also cleaning is one of the best ways to check for abnormalities and dealing with them at the early stage.

6. 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. Here all industries should have at least one planner, who can manage this task, to have effective preventive maintenance schedule.

7. Spare parts should be managed well by classifying them as consumable, standard, and special spare part for every equipment to facilitate the ordering process.

8. Any preventive maintenance activities should be given emphasis, as it is the only solution to increase the availability of equipment. Thus maintenance and production has to be integrated with a common goal of the company 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 preventive maintenance activities and should provide the equipment whenever needed.

9. The work order system should be available for all activities done in the maintenance department to measure or control the activities. Moreover, if they use the developed

computer program, they will be much benefited in data recording system and for ease retrieval of information concerning the maintenance activities.

10. Since the very nature of production in tanneries is continuous, that is hide or skin is perishable unless continually processed, and varies with time, the situation calls for condition based maintenance system to be efficient and effective. And also condition monitoring instruments and tools, which makes the time taken for failure analysis and repairs short, should be available.

11. *Complete staffing* method is recommended for big capacity leather industries to be fully staffed for every maintenance activities for their own as well as to support other leather industries. For medium production capacity leather industries a *combined in-house/contract staffing* method is recommended to decrease the number of workforce required for specific operations. Small leather industries can use a *contract maintenance staffing* method to be cost effective because, they have relatively small number of machines.

12. All leather industries should work together to support each other concerning the maintenance activities. For example, the maintenance department of Ethiopia Tannery Share Company should be well equipped and staffed to support other medium and small tanneries taking this as one of income generation. It is much more expected from Ethiopia Tanners Association to coordinate and facilitate this.

13. Finally, further studies can be made on the productivity improvement in Ethiopian leather industries through capital resource other than maintenance and through human resource. Since leather industries are one of the potential economic sector, further studies on the mentioned areas helps to earn more for the country.

References

1. John R. Schermerborn, Jr., ***Management for productivity,*** 4th edition, Chichester Brisbane, New York, 1993
2. Terry Wireman, ***World Class Maintenance Management***, Industrial Press Inc., New York, 1990
3. John E. Heintzelman, ***The Complete Handbook of Maintenance Management***, 4th printing, Pretice-Hall, Inc./ Englewood Cliffs, N.J. 1979
4. Joel Levitt, ***The Hand Book of Maintenance Management***, Industrial Press Inc., New York, 1997
5. Higgins and Morrow, ***Maintenance Engineering Handbook***, 3rd edition McGraw Hill, USA, 1997
6. Goplakisshnan, P. and Beneji, k.a., ***Maintenance and spare parts Management***, Prentice-Hall of India, New Delhi,1997
7. Bailey and Hubert, ***Productivity Measurement***, Lowe & Brydone printers Limited, Thetford, Norfolk, Great Britain, 1980
8. J. H. Sharphouse, ***Leather Technician's Handbook***, Page Bros, Norwich Great Britain, 1995
9. Joseph Prokopenko, ***Productivity Improvement a Practical Handbook***, Oxford & Ibh Publishing Co, New Delhi, 1999
10. Kunio Shirose, ***TPM for Workshop Leaders***, Productivity Press, Portland, Oregon, 1992
11. Assomac, ***The Tanning Engineering Notebooks***, Assomac Servizi srl, Vigevano, Italy 2002
12. Ethiopian Tanners Association, ***Ethiopian Leather Journal***, Special publication for meet in Africa, Volume 1, Issue No.I, December 2004
13. P. Gopalakrishnan & A.K. Banerji, ***Maintenance and Spare Part Management***, Prentice-Hall of India PLC, New Delhi, 2002.
14. Ethiopian Science and Technology, Ethiopian Cleaner Production Center, ***Ethiopian Experience on Environmental Management System Implementation towards ISO 14001 Certification***, Addis Ababa, April 2005

15. Hildebrand, James K., ***Maintenance Turns to the Computer***, Cahners publishing company Inc., Pennsylivania, 1972
16. Moubray, John, ***Reliability Centered Maintenance***, Butter worh heineman Ltd., Boston, 1997
17. Moss, Marrvin A., ***Designing for Minimal Maintenance Expense***, Syscon Corporation Montrose, California, 1985
18. Kelly, Anthony, ***Maintenance Strategy, Business – Centered Maintenance***, Butter Worth Heineman, Boston, 1997
19. Hodson, William K., ***Maynard's Industrial Engineering Handbook***, McGraw-Hill, New York, 1992
20. Dunlop, C. L., ***A practical Guide to Maintenance Engineering***, Butterworth and Co. Ltd., London, 1990
21. Raouf, A. and Ben-Daya, M., ***Total Maintenance Management: A Systematic Approach***, Journal of Quality in Maintenance Engineering, Vol. 8 No. 4, 2002, pp. 287-305
22. Ireland, F., and Dale, B.G., ***A Study of Total Productive Maintenance Implementation***, Journal of Quality in Maintenance Engineering, Volume 7 Number 3 2001 pp. 183-192
23. http://www.leathernet.com/
24. http://scholar.lib.vt.edu/theses/available/etd-01102005-191255/unrestricted/Assessment_Of_Dynamic_Maintenance_Managament.pdf.
25. http://ravi.lums.edu.pk/cmer/upload/Common_Factors_in_Productive_Firms.pdf.
26. http://www.uwstout.edu/lib/thesis/2000/2000gutierrezf.pdf.
27. http://grace.wharton.upenn.edu/~lhitt/bpp.pdf.
28. http://www.oecd.org/dataoecd/59/29/2352458.pdf.
29. http://www.ilo.org/dyn/empent/docs/F1715412206/New%20Concepts%20of%20Productivity.pdf.

Appendix A - The Tannery Processes

The tannery process of the company consists of a series of physical and chemical operations to convert the hide or skin to leather. Leather is any animal hide or skin that has been processed to have good flexibility, high tensile strength, abrasion resistant, and good appearance for use by man. Large animals are said to have hides, while small animals have skins. In either case, the hide or skin is organic material composed of water and proteins and unless preserved, decays quickly.

To analyze the process, it is important to subdivide it in to three phases. The first phase is from raw material to tanned state (wet blue), the second phase is from wet blue to crust (dry dyed), and the third phase is from crust to finished hide.

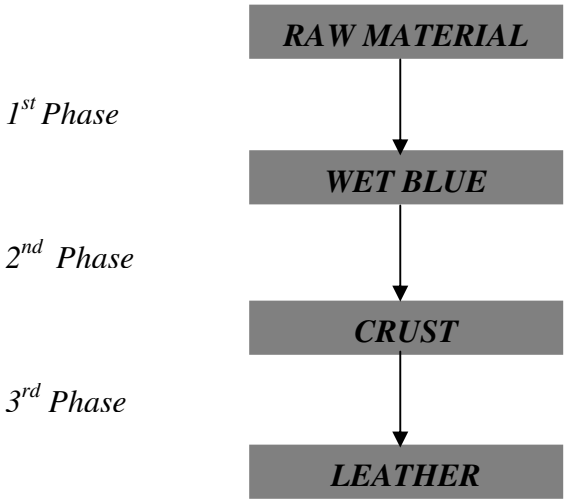

Fig A.1 Tannery process flow

Each of these phases are discussed below

1st Phase – From Raw material to Wet blue

In this phase the rawhide or skin is changed to wet blue state. Here most of the machines are drum and the process is as follow.

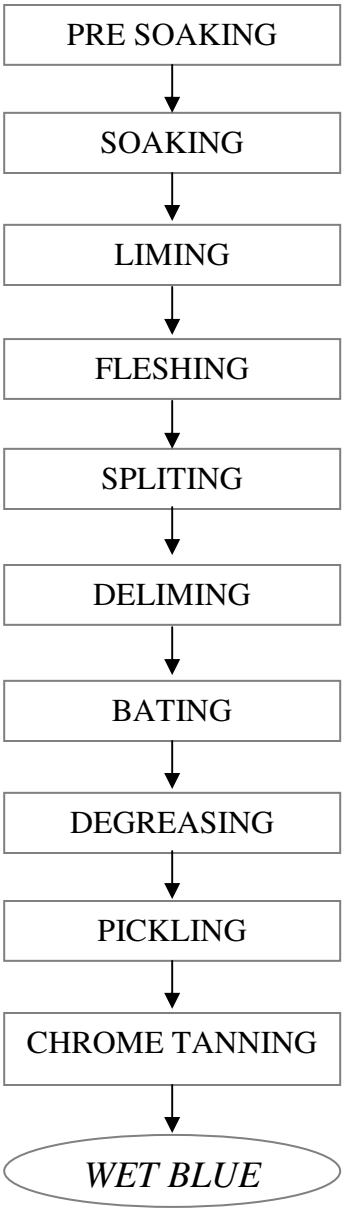

Fig A. 2. Tannery process from rawhide or skin to wet blue state

2nd Phase – From Tanned to Crust

In this phase the tanned hide or skin that is wet blue stage is changed to crust state. The process is as follow.

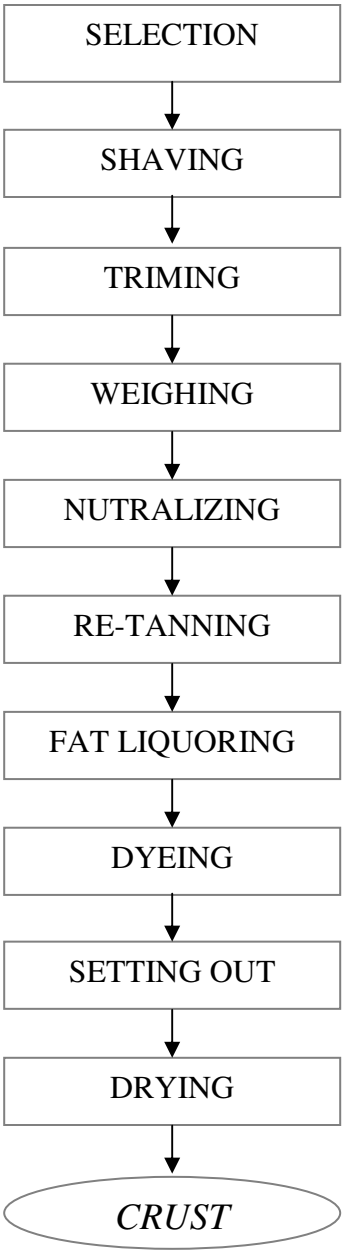

Fig A. 3. Tannery process from wet blue to crust state

3rd phase - From Crust to Leather

Finishing operation is the mechanical modification of the hide or skin outer appearance and such properties as elasticity, softness, and feel by adhering an aesthetic covering polymeric film to the derma. The process is as follow:

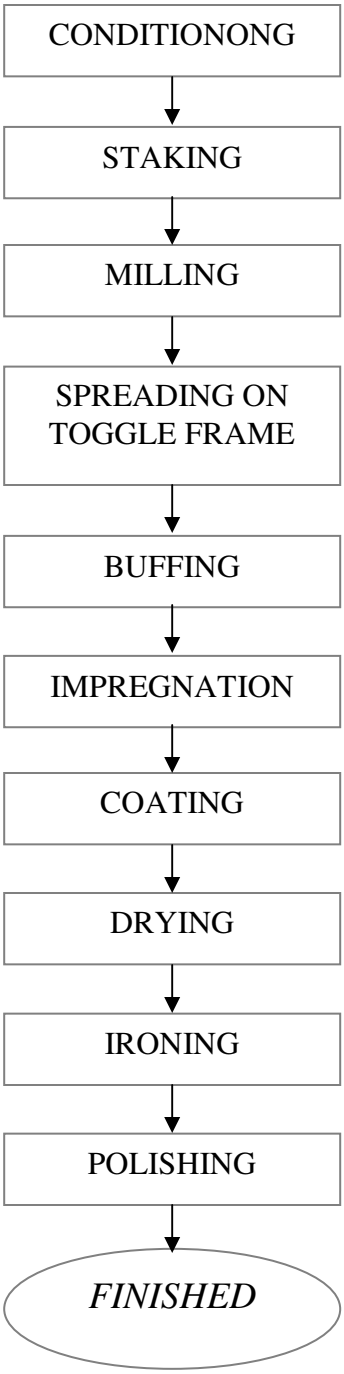

Fig A. 4. Tannery process from crust state to finished leather

Appendix B - Definition of Terms

Bating – is a process to give a smoother grain and render the skin soft and flexible by using proteolytic enzyme as a fundamental for determining the particular characteristics of the finished product (smooth grain, soft hide, etc).

Buffing – is a mechanical operation to remove the grain completely to obtain soft and opaque surface, to make the flesh side of the leather to be refine and smooth, or to remove a more or less significant amount of surface material from low quality hides.

Coating – is the application of natural or synthetic products, generally water-based, for coloring, covering, sealing effects and for giving body to the leather.

Conditioning – is a process to provide moisture in to the dried hide or skin to eliminate the occurrence of cracking for the next operation.

Degreasing – is the operation designed to remove most of the accumulation of fat and uniformly distributes the remaining fat over the hide surface.

Deliming – is a process of immersing the hide in a weak solution of acid, which used to reduces the swelling caused by the lime, eliminate free an combined lime to establish the ideal conditions for batting and to reduce the amount of solid in suspension.

Drying – is an operation to reduce the moisture content from 70% to 20-22%. It is performed in the company through Vacuum drying, toggle frames, or overhead chain.

Dyeing – is a process of giving a required color characteristics. A good dyeing have good color uniformity, maximum color depth with the list amount of dye possible, good defect cover and high color light – fastness.

Fatliquoring – is done to lubricate the dermic fibers to avoid gluing and to provide the finished article with fullness and softness.

Fleshing – is a first mechanical operation carried out on the hide to separate the subcutaneous tissue, fat and flesh from the derma.

Hide – is the outer covering of large animal's body. Or large animal's skin, eg. cow

Impregnation – is an operation aims at increasing the ability to adapt to the extension and compression caused by folding, generating a more elegant behavior.

Ironing – is pressing and imposing operation to give various pattern to the leather. It performed in two different machines, flat presses that work in a discontinuous manner or a cylindrical rotary presses that work in a continuous manner.

Leather – is any animal hide or skin that has been processed to have good flexibility, high tensile strength, abrasion resistant, and good appearance for use by man

Liming - is a process of immersing in a solution of lime and water containing a small amount of sodium sulfide to eliminate the hair and to open the fibrous network of the derma to make the hide more readily react to the fixing of the tanning substance.

Milling – is a mechanical process to improve the softness of the leather and gives the grain a more precise design. A drum similar to the one used in the wet phases is used.

Neutralizing – is removal process of the free acid present in the leather, to assure stability in heated conditions and resistant to boiling.

Pickling – is a process of making the hide's PH value very good for doing the tanning process, especially for carrying out the chrome tanning. The drum used for this process should be provided with an adequate extraction system for removing the toxic gas, hydrogen sulphide.

Polishing – is the last finishing operation to provide a shiny appearance and pleasant feel.

Reliability – is the probability that the equipment will perform a specified function, under specified conditions for a specified time.

Retanning – is a process to give the material the required uniform fullness and ability to retain their consistency after the drying process that tend to flatten the hides and reduce their thickness.

Setting out – is a process of pressing the leather to reduce the residual moisture in the hide from 100% to 65-70%. It also helps the hide to be widened and the grain to be flattened.

Shaving – is a mechanical process to even the hide thickness and permit grater precision than is possible by splitting.

Skin – is the outer covering of small animal's body, eg. sheep and goat

Soaking – is a process of immersing the cured hides or skins in pure water to eliminate salt, blood, and dirt, and also to replace moisture lost in the curing process. Paddles are used for soaking hide or skin. Soaking in the paddle is takes place with gentile mechanical motion and over a long period of time.

Splitting – is the second mechanical operation performed on the hide on the transformation process, by splitting the derma in tow portions to make the derma thinner than the natural thickness and level the outer surface.

Spreading on toggle frame – is a useful operation of spreading out the hide under tension on the toggle frame and allow to dry in a hot air tunnel for a short period of time, but long enough to reduce the humidity from 22-24% to 15-16%. The objective of this operation is to take the advantage of the detachment of the fibers to spread and flatten the hides as much as possible.

Staking – is a mechanical operation to make the hide softer and more pliable. A residual humidity of 20-22% favors the lubricating necessary for allowing the fibers not to break.

Tanning – is a process to make the tanning material penetrate and become fixed in the hide to establish the dermic tissue and halt its degradation. There are many substances that can be used for tanning.

> *Chrome tanning* – is a tanning process, which most frequently used salt compound of chromium as a tanning agent.
>
> *Vegetable tanning* – is a tanning process, which used a substance called tannin, extracted from the bark, wood, fruit, and leaves of trees.

.

Appendix C - Questionnaires

The questioner, which is distributed to selected leather industries in Ethiopia to know where the maintenance department stands, is prepared for maintenance personals especially for supervisors or managers. It is organized in to six parts, the first part request how the maintenance department in the companies is organized. The second part asks for, how the company trains maintenance personnel. The next two parts appeal how work orders and planning are performed respectively. Finally, the way preventive maintenance, purchasing and inventory process accomplishment are asked in two parts.

Part 1 Maintenance Organization

1. Sketch maintenance organizational chart
2. Job description are available for:
   - ☐ All maintenance positions (including supervisors)
   - ☐ All maintenance positions (except supervisors)
   - ☐ All maintenance supervisors (and no others)
   - ☐ No job descriptions
3. Maintenance organization effort and attitude:
   - ☐ Excellent pride in workmanship at all levels
   - ☐ Steady work rate, professional operation
   - ☐ Average work speed, only few complaint
   - ☐ Only occasional good efforts, frequent job delays, many complaints
   - ☐ Constant disagreement within maintenance organization and between maintenance and production
4. Maintenance shop work area location:

   ☐ Perfect ☐ Fair ☐ Unsuitable or nonexistent
   ☐ Good ☐ Poor
5. Maintenance shop work area layouts:

   ☐ Perfect ☐ Fair ☐ Unsuitable or nonexistent
   ☐ Good ☐ Poor

6. Maintenance tools/equipment quality and quantity:

☐ Perfect	☐ Fair	☐ Unsuitable
☐ Good	☐ Poor	or nonexistent

Part 2 Training program in maintenance

1. Supervisory training:
   - ☐ All are trained when salaried and additional training is mandatory on scheduled basis
   - ☐ All are trained when salaried and additional training is offered on an optional basis
   - ☐ The majority are trained when salaried
   - ☐ The majority are offered and attained training offered on an frequent or irregular basis
   - ☐ Few are given initial training and little or no additional training is provided
2. Planner/scheduler training:
   - ☐ All have been to one or more public seminars providing instruction on maintenance planning and scheduling
   - ☐ All are provided with a written training program for maintenance planning
   - ☐ All receive one-on-one on the job training at least 1 month
   - ☐ Planner/scheduler training is on the job
   - ☐ There is no planner/scheduler training program
3. General quality and productivity training:
   - ☐ Includes upper management, line supervision, hourly worker, support personnel
   - ☐ Include upper management, line supervision, hourly workers
   - ☐ Include upper management, line supervision
   - ☐ Is only for upper management
   - ☐ No training program
4. Maintenance craft training:
   - ☐ Training is tied to a pay and progression program
   - ☐ Formal job experience is required before employment and on the job training is provided
   - ☐ Formal job experience is required before hire
   - ☐ Training is provided by on the job experience after hire

- ☐ There is no formal training requirements for hire and no subsequent training is provided

5. Maintenance training intervals: formal maintenance training is provided to all maintenance craft employees at the frequency of:
   - ☐ Less than one year
   - ☐ B/n12 and 18 months
   - ☐ B/n 18 and 24 months
   - ☐ Not provided to all employee but to some in any of the above frequencies
   - ☐ No training is offered
6. Format of maintenance training:
   - ☐ Training is a mix of classroom and lab exercises
   - ☐ Training is all classroom
   - ☐ Training is all in lab or workshop environment
   - ☐ Training is all on job
   - ☐ No formal craft training program exists
7. Training program instruction:
   - ☐ Training is done by outside contract expert
   - ☐ Training is done by staff subject expert
   - ☐ Training is done by supervisors
   - ☐ Training is done by hourly workers
   - ☐ Training program does not exist
8. The quality and skill level of the maintenance work force is:
   - ☐ Perfect ☐ Fair ☐ Unsuitable or nonexistent
   - ☐ Good ☐ Poor
9. The quality and skill level of supervisor group is:
   - ☐ Perfect ☐ Fair ☐ Unsuitable or nonexistent
   - ☐ Good ☐ Poor

Part 3 Maintenance work orders

1. What percentage of maintenance man-hours are reported to a work order:
   - ☐ 100% ☐ 50% ☐ Less than 25%
   - ☐ 75% ☐ 25%

2. What percentage of total jobs performed by maintenance are covered by work orders:

   ☐ 100% ☐ 50% ☐ Less than 25%

   ☐ 75% ☐ 25%

3. What percentage of the work orders are available for historical data analysis:

   ☐ 100% ☐ 50% ☐ Less than 25%

   ☐ 75% ☐ 25%

4. What percentage of the work orders are checked by the supervisor for work quality and completeness:

   ☐ 100% ☐ 50% ☐ Less than 25%

   ☐ 75% ☐ 25%

5. What percentage of the work orders are generated from the preventive maintenance inspection

   ☐ 100% ☐ 50% ☐ less than 25%

   ☐ 75% ☐ 25%

Part 4 Maintenance planning and scheduling

1. What percentage of non-emergency work orders are completed within four weeks of the initial request?

   ☐ More than 90% ☐ B/n 60 and 75% ☐ Less than 40%

   ☐ B/n 75 and 90% ☐ B/n 40 and 75%

2. Percentage of planned work orders experiencing delays due to poor or incomplete plants:

   ☐ Less than 10% ☐ B/n 20 and 40% ☐ More than 50%

   ☐ B/n 10 and 20% ☐ B/n 40 and 50%

3. Who is responsible for planning the work orders:

   ☐ Dedicated maintenance planner ☐ Each craft worker

   ☐ A maintenance supervisor

4. Maintenance job schedules are issued

   ☐ Weekly ☐ B/n 3 and 7 days ☐ Any other frequency

   ☐ Biweekly ☐ Daily

5. The maintenance and production scheduling meeting is held:
   - ☐ Weekly
   - ☐ B/n 3 and 7 days
   - ☐ Any other frequency
   - ☐ Biweekly
   - ☐ Daily
6. When the job is completed, the actual time, material downtime, and other information is reported by:
   - ☐ The craftsmen
   - ☐ Anyone else
   - ☐ The supervisor of the group
   - ☐ Information is not recorded
7. What percentage of the time are the actual compared to the estimates for monitoring planning effectiveness:
   - ☐ More than 90%
   - ☐ B/n 60 and 75%
   - ☐ Less than 40%
   - ☐ B/n 75 and 90%
   - ☐ B/n 40 and 75%
8. What is the reporting relationship between planners and supervisors:
   - ☐ Both report to the same maintenance manger
   - ☐ The planner reports to the supervisor
   - ☐ The supervisor reports to the planner
   - ☐ The supervisor and planner report to operations/facilities

Part 5 Preventive Maintenance

1. The preventive maintenance (PM) program includes:
   - ☐ Lubrication checklists
   - ☐ Detailed inspection checklists
   - ☐ Personnel specifically assigned to the PM program
   - ☐ PM diagnostics such as vibration analysis, oil sample analysis, infrared heat monitors, etc.
2. What percentage of the PM inspection/task checklist are checked to ensure completeness:
   - ☐ More than 90%
   - ☐ B/n 60 and 75%
   - ☐ Less than 40%
   - ☐ B/n 75 and 90
   - ☐ B/n 40 and 75%
3. What percentage of the plant critical equipment is covered by a PM program:
   - ☐ More than 90%
   - ☐ B/n 60 and 75%
   - ☐ Less than 40%
   - ☐ B/n 75 and 90%
   - ☐ B/n 40 and 75%

4. What percentage of the PM program is checked against an equipment item's history annually to ensure good coverage?
   - ☐ More than 90%
   - ☐ B/n 60 and 75%
   - ☐ Less than 40%
   - ☐ B/n 75 and 90%
   - ☐ B/n 40 and 75%
5. What determines the frequency of a PM inspection or task/service interval?
   - ☐ Program is condition based
   - ☐ Program is based on a combination of equipment run time and fixed calendar interval
   - ☐ Program is based on equipment run time only
   - ☐ Program is based on calendar intervals
   - ☐ Program is dynamic and is scheduled based on completion date of previous task
6. Who is responsible for performing PM tasks?
   - ☐ Dedicated PM personnel
   - ☐ Any individual on a crew
   - ☐ Specific individuals on each crew
   - ☐ Operating personnel

Part 6 Maintenance inventory and purchasing

1. Who controls what is stocked as maintenance inventory items?
   - ☐ Maintenance
   - ☐ Anyone else
2. Maximum and minimum levels for the maintenance stores items are specified for what percentage of the inventory?
   - ☐ More than 95%
   - ☐ B/n 80 and 90%
   - ☐ Less than 70%
   - ☐ B/n 90 and 95
   - ☐ B/n 70 and 80%
3. Are the different parts stored in order, so that; there is no difficulty to locate the needed item?
   - ☐ Yes
   - ☐ No
4. A recorder list is sent to purchasing
   - ☐ Daily
   - ☐ Weekly
   - ☐ Every 1-3 days
   - ☐ Any other frequency

Appendix D - Organizational Structure of the Maintenance Department of Ethiopia Tannery S. Co.

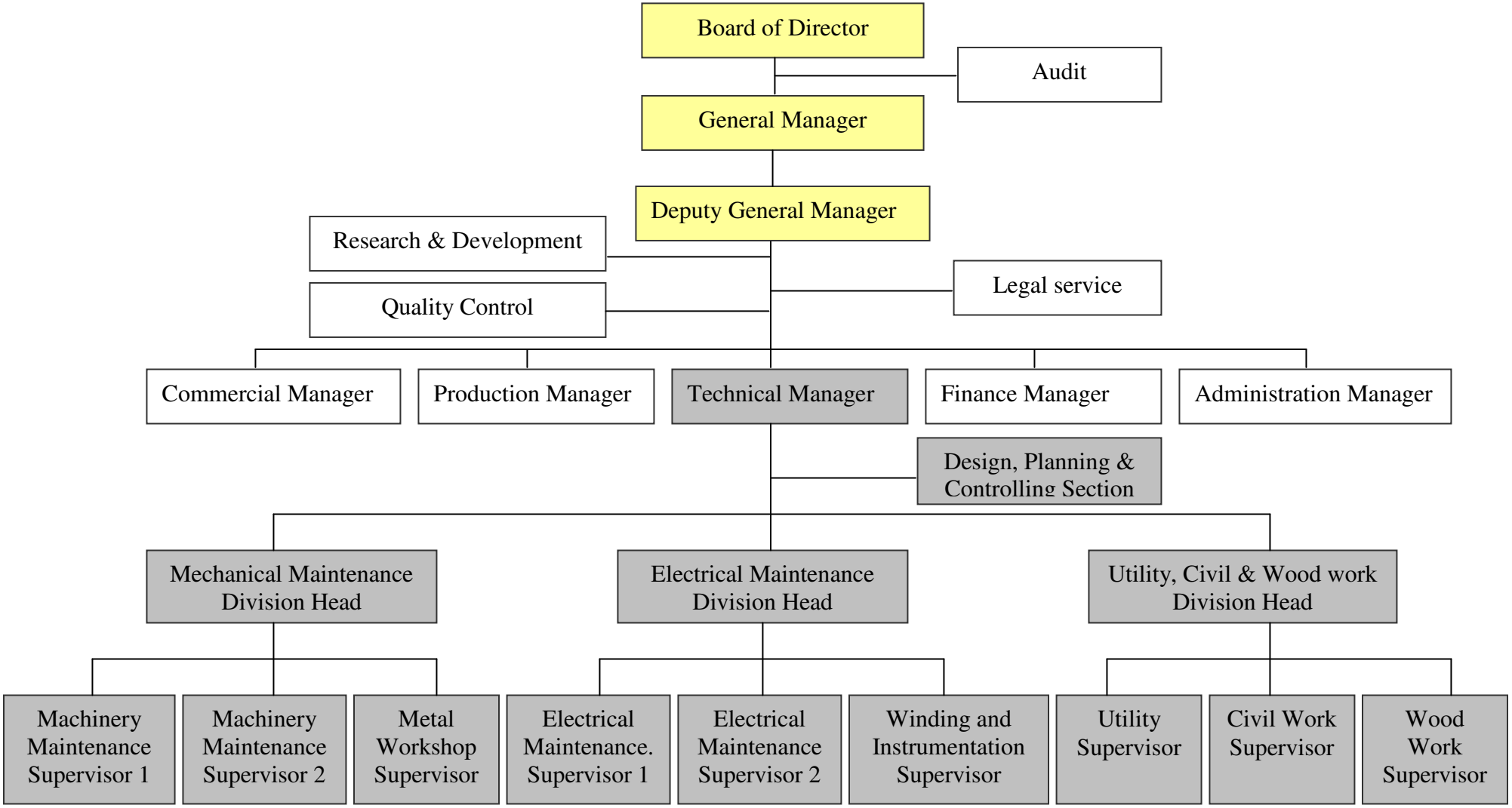

Fig. D.1 Organizational structure of the maintenance department of Ethiopia Tannery S. Co.

Appendix E – List of Contacted Leather Industries

No	Name of the Company	Contacted Person	Title	Address	
				Location	Tele
1	Ethiopia Tannery	Ato Bisrat Aklilu	Technical M.	Edgersa	02-114586
2	Addis Ababa Tannery	Ato Solomon Getu	General M.	Addis Ababa	01-575311
3	Batu Tannery	Ato Abdela Ismael	Technical M.	Addis Ababa	01-391435
4	Walya Tannery	Ato Birhanu Belay	Technical M.	Addis Ababa	01-422367
5	Shewa Tannery	Ato Daniel Desalegn	Technical M.	Modjo	02-160071
6	Modjo Tannery	Ato Alemante Kasa	Technical M.	Modjo	02-160016
7	Colba Tannery	Ato G/Micael Megersa	Prod. & Tech. M.	Modjo	02-160893
8	ELLPI	Ato Solomon Asfaw	Technical M.	Addis Ababa	01-391700

Table E.1 List of contacted leather industries with contacted persons