Enhancing Productivity through Improved Maintenance System

(Case Study in Dashen Brewery Share Company)

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I hereby declare that the work which is being presented in this thesis entitle: “Enhancing productivity through improved maintenance system (case in Dashen Brewery Share Company) is original work of my own, has not been presented for a degree of any other university and all the resources of materials used for the thesis have been duly acknowledged.

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ABSTRACT

Maintenance is the combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to a state in which it can perform the required function. Nowadays, many of the industries in our country faced with the problem of maintenance which results in poor productivity. Therefore, improved maintenance system is an important task to enhance the productivity. In this study, the maintenance problems of Dashen Brewery Share Company and development of improved maintenance system were studied. The study were assessed the existing maintenance system of the company, differentiate the factors affecting productivity, investigate and analyze the maintenance problems.

Two sets of data which are required for the study are collected from the company, data has been obtained from a structured questionnaire response which is distributed for a sample size of 60 respondents drawn from Dashen Brewery Share Company maintenance department workers and machines downtime data were obtained from the annual recorded report of the company.

The collected data have been analyzed by analytical tools, which are Microsoft Excel, Pareto and SPSS analysis and proposed solution is given to improve the productivity of the company. These analyses are used to identify the key area which faces high downtime in the case company. In filler machine the filling valve is the critical component which causes the loss of production. Since the designed production capacity of the industry is 48,000 bottles/ hr and its actual production capacity is 31,000 bottles/ hr which means the industry produces 64.5% of its designed capacity and the company losses 82,442,775.21 birr/hr due to machine downtime and maintenance. This has resulted from the poor reliability of their production systems as a result of poor or insufficient maintenance. But if the industry implements the proposed solution, the company almost meets the planned capacity, i.e. 42,000 bottles/hr, which is the industry produces 87.5% of its designed capacity and the loss of money due to maintenance and downtime costs the company increases the profit by 17.41% and can improve the productivity. The results show the importance of the development of maintenance strategies through the implementation of RCM in this company and depending on the problems the model is developed. The purpose of it would be to overcome the problems that could secure the reliability of the production systems.

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LIST OF ABBREVIATIONS

CBM - Condition based Maintenance

CM - Corrective Maintenance

DBSC – Dashen Brewery Share Company

DT – Down Time

EBC – Empty Bottle Conveyors

EBI – Empty Bottle Inspection

FBC – Full Bottle Conveyors

FMEA – Failure Mode and Effect Analysis

FMECA - Failure Mode and Effect Critical Analysis

LCC - Life Cycle Cost

OEE - Overall Equipment Effectiveness

PDM - Predictive Maintenance

PE – Performance Efficiency

PM - Preventive Maintenance

QR – Quality Rate

RCFA – Root Cause Failure Analysis

RCM - Reliability Centered Maintenance

SPSS - Statistical Package for Social Sciences

TPM - Total Productive Maintenance

CHAPTER ONE

INTRODUCTION

1.1. Background

In recent decades, production system maintenance has evolved to be one of the most important areas in the business environment. The growth of global competition caused remarkable changes in the way of manufacturing companies operation. These changes have affected maintenance and made its role even more essential in business success. Implementing maintenance concept is one of the significant changes in manufacturing companies. The companies use supporting function to progress their activities. Maintenance as a significant part of activities impacts on production performance (Akao, 1990).

Due to increasing of automation and mechanization, production processes are shifting from manual to machines. Today the world is working in one faced global market and to be competitive, every industry is striving to improve the productivity through different types of tools, techniques, systems and philosophies. Improved maintenance system is used in different types of manufacturing industries.

The role of maintenance must change to support the growing worldwide competition. It can no longer limit its role to immediate reaction to emergencies and overpower problems with more bodies and excessive overtime. In other words, maintenance should not always be reactive rather it should be proactive. In this regard, there is a need of executing maintenance more effectively. If the right systems, infrastructure, processes, and procedures are in place and consistently executed well, losses can be minimized; the operation will become stable; production output will be maximized; and consistently high product quality will become the norm. We call this a state of maintenance excellence. Maintenance excellence is a subset of reliability excellence and redefines the traditional roles and responsibilities, as well as the maintenance processes that are necessary to assure asset reliability, maximum asset useful life and best life cycle asset cost (Narayan, 2011). It is run like any other for-profit business and expected to meet its critical contribution to a fully integrated plant organization (Alsyouf, 2007). All of these results are significant reductions in maintenance spending. It is not unusual for organizations to experience as much as a 50 % reduction in maintenance cost as a result of moving from a reactive style of management to a proactive approach (Pun et ai., 2002). Proper 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.

Productivity is the relationship between what comes out of an organizational system (assuming that the output meets the attributes established for them) divided by what comes into the system (i.e. labor, capital, material etc.) during a given period of time (Lofsten, 1999).

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. The impact of maintenance on business performance aspect such as productivity and profitability has increased indefinitely in recent times due to its role in ensuring and improving machine availability, performance efficiency, product quality and swift delivery, environmental and safety requirements (Swanson, 2001).

Therefore, one of the main areas for productivity improvement is maintenance and so the research focuses on how to improve the productivity of Dashen Brewery Share Company through effective maintenance system in order to follow proper maintenance system.

1.2. Statement of the Problem

Keeping assets efficiency consistently through maintenance system is a requirement to attain companies' business goals. Yet, inefficient maintenance practices result in huge impact on production quality, productivity and profitability. Most organizations in Ethiopia lack efficient maintenance management system that affects the total output (Misikir, 2004) (Meseret, 2007).

DBSC is one of the largest processing factories in Ethiopia with a long process to have an output with the big capacity. In this factory machines are arranged sequentially to process their own intended activities and the designed production capacity is 48,000 bottles/ hr. However, in the preceding day to day activity there are reasons not to meet the planned capacity. Of such as mechanical, electrical, utility, maintenance program and others are included among problems which are reasons for high downtime and an effect for reduced capacity. Mechanical down times existed on packaging section rather than others sections and this down time which results in low capacity that couldn't be achieved in real situation. Because in this section key area for down time is the filler machine, specifically the filling valve and this critical component decreases the production capacity due to under filling problem, i.e the planned loss due to under filling is 0.2 % of the total production capacity/day but now the actual loss due to under filling is 1.5% of the total production/day. As the plan is to meet 42,000 bottle/ hr however this also can't be achieved so they produced below the designed and planned capacity that is an average of 31,000 bottle/ hr. The existing down times in this section are quantified as 40% mechanical down time, 23% electrical down time, 24% maintenance program (not follow maintenance schedule which has to start on Monday). For this reduced production capacity of the problem is mainly associated with less performing proper maintenance (Brewery, 2015/2016). Those all mechanical down times have resulted in highest percentage which needs proper maintenance processes.

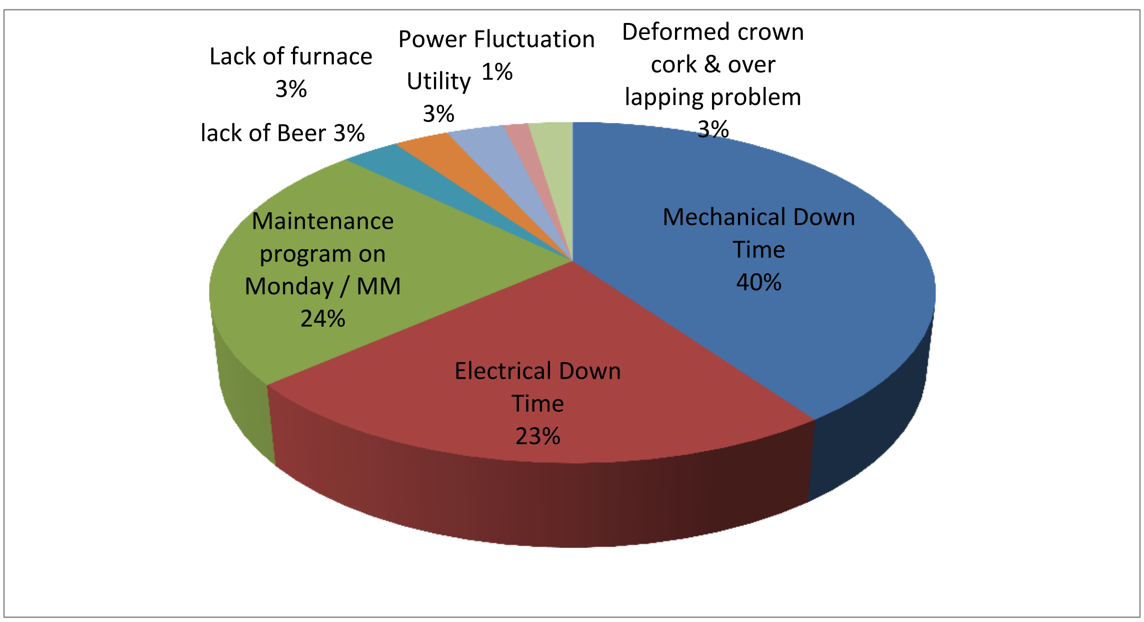

Figure 1.1. Division of down time in Dashen Brewery 2015/2016 (Brewery, 2015/2016)

The absence of proper maintenance practices lead the company to high maintenance cost of the machine spares and exposed for functionless machines. The motivating factor to work in this thesis is the absence of proper maintenance in DBSC which reduces the productivity and profitability of the factory. Thus, it is logical to assess the maintenance practice in the case company to improve machines efficiency and maximize productivity.

1.3. Basic Research Questions

The research work consist four main questions as a guiding question in order to meet the objectives and develop maintenance system to the company. The questions include:

1. What is the present maintenance system in Dashen Brewery Share Company (DBSC)?
2. What are the major problems in the current maintenance system on DBSC?
3. What are the causes of poor maintenance in the DBSC?
4. How can maintenance operation in a production system improve productivity on DBSC?

1.4. Objectives

1.4.1. General objective

The main objective of this thesis is to enhance the productivity through improved maintenance systems of DBSC.

1.4.2. Specific objectives

The specific objectives of this research are:

- To assess the existing maintenance system of the DBSC.
- To identify the maintenance related problems and root cause of the problems of the DBSC.
- To prioritize the factors that affect maintenance system using FMEA.
- To propose a model that improves maintenance system.

1.5. Significance of the Research

The research has a vital role to the company on bringing the expected target as stated in the title. It can play an endless role in keeping machines continuous performance and improve high downtime of machine due to lack of proper maintenance. And it can bring good productivity and will reduce maintenance cost and increase product quality. To the company and outside community, as per the plan it can make easy their work and be competitive on offering products on time respectively. This research has been used as an input for better and further researchers.

1.6. Scope of the Research

The study was conducted in DBSC which is located in Gondar Town. To analyze and improve productivity through maintenance system, packaging section has been selected and not take into consideration of other sections; because, the problem that explained in this thesis was occurred in packaging section other than others and this section has been a number of machines with a long process and is a main production section to have an output of beer.

1.7. Limitation of the Study

The RCM system framework proposed for DBSC maintenance was not practically implemented due to inadequate time and resource demanded for the activities to be carried out including training, resource allocation and other arrangements to be taken in the process.

1.8. Overall Organization of the Study

The chapter wise detail of the thesis are as follows: chapter one discuss the introduction and objectives of the paper, chapter two deals with the literature studies conducted by various researches in the area of productivity and maintenance concept, the methodology that how to conduct this research is described in chapter three, the data collection and analysis for DBSC has been discussed in chapter four, chapter five the propose solution for the maintenance problems in the company, chapter six refers to the conclusion and recommendation.

CHAPTER TWO

RELATED LITERATURE REVIEW

2.1. Overview of Maintenance

The main objective of this section were to provide a description and prons and cons of common maintenance system and consider in detail, according to author's point of view, the most relevant for the current research.

2.1.1. Definition Term

Maintenance is defined according to the European standard (Alsyouf , 2004) as "the combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to a state in which it can perform the required function". Also in the same vein, maintenance are needed for keeping a system/ product within its life cycle in a functional, operative and condition, or restoring it to a state it can perform the intended function.

Maintenance activities are multidisciplinary in nature with a large number of inputs and outputs, the performance of maintenance productivity needs to be measured and considered holistically with an integrated approach. With increasing awareness that maintenance creates added value to the business process; organizations are treating maintenance as an integral part of their business (Liyanage & Kumar, 2003). Therefore, the performance of the maintenance process is critical for the long term value creation and economic viability of many industries. It is important that the performance of the maintenance process be measured, so that it can be controlled and monitored for taking appropriate and corrective actions to minimize and mitigate risks in the area of safety, meet societal responsibilities and enhance the effectiveness and efficiency of the asset maintained (Wireman, 1990). A measure commonly used by industries is the maintenance performance for measuring the maintenance productivity.

Productivity is defined as the ratio of the output to input of a production system. The output of the production system is the products or services delivered while the input consists of various resources like the labor, materials, tools, plant and equipment, and others, used for producing the products or services. (John & Schermerborn, 1993).

Productivity is application of the various inputs resources of an organization, industry or country, in order to achieve certain planned and desired outputs. Productivity improvement thus becomes the establishment of approaches to improve this productivity index (Attia, 2006) (Yilmaz, 2009). It is effective and efficient utilization of resources used to produce products/services that meet customer requirements continuously by applying appropriate methods and by controlling the parameters. (Nekajima, 1999).

Productivity is a function of the production process efficiency and effectiveness. Evaluating maintenance profitability, the impact on other working areas is also measured (e.g. by affirming maintenance role in machine life cycle profit) (Obamwonyi, Martyn, & Aimienrovbiye, 2010). Maintenance improvements in general aim at reducing cost of operation and improving product quality, thus, the cost effectiveness of each improvement action may well be scrutinized through evaluating the relevant cost constraint before and after improvements.

Effective maintenance aims to enhance company's profitability and competitiveness through continuous cost-effective improvement of production process efficiency, effectiveness and productivity, which can be achieved via maintaining and improving the quality of all the elements contribute in the production process continuously and cost-effectively (Maletic, Maletic, Al-Nejjar, & Gomiscek, 2012), (Narayan, 2011).

2.2. Productivity Measurement and Factors

Productivity 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 (Prokopenko & Joseph, 1999).

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 (Hubert, 1980).

Among those the most general one is classifying it into 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 (Maletic, Maletic, Al-Nejjar, & Gomiscek, 2012). 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.

The internal factors, which can be controlled in short run, are product, equipment, technology, materials, energy, people, organization and management style (Prokopenko & Joseph, 1999).

2.3. Productivity Improvement

Improving productivity has a positive impact on the direct costs of the products, as the same output is produced with less input or as the same inputs are producing more output. This can create new opportunities and improve the competitiveness of the manufacturing operations.
Low productivity indicates that an enterprise is wasting its resources, and this means that it were eventually lose its international competitiveness and thereby reduce the scale of its business activities. Low productivity decreases the growth of a nation's industries and economy as a whole (Rana & Arif, 1997). Improving productivity is especially important for export oriented industries since it is the only viable option for competing in the long term.

A framework for maintenance concept development, takes into account both computerized information and ‘knowledge’ (worker experience, know-how) (Geert & Liliane, 2002).

2.4. Maintenance and its Impact on Business Processes

According to (Al- Najjar & Alsyouf, 2004) the significance of maintenance function has over the years increased due to its role and impact on other working areas (e.g. production, quality, etc.) in an organization, i.e. improving machine availability and product quality. Efficient maintenance contributes by adding value through better utilization of resources (i.e. higher output), enhancing product quality as well as reducing rework and scrap (i.e. lower input of production cost) (Alsyouf, 2004). In addition, the increasing awareness of maintenance and its influences on both industrial and the society at large can be recognized.

Many researchers and practitioner have emphasized on the total losses caused by maintenance omission or ineffectiveness in maintenance. Nonetheless, maintenance is still considered as a cost center based on the survey conducted on 118 Swedish manufacturing companies where 70 percent of the respondents consider maintenance as a cost center (Alsyouf, 2007).

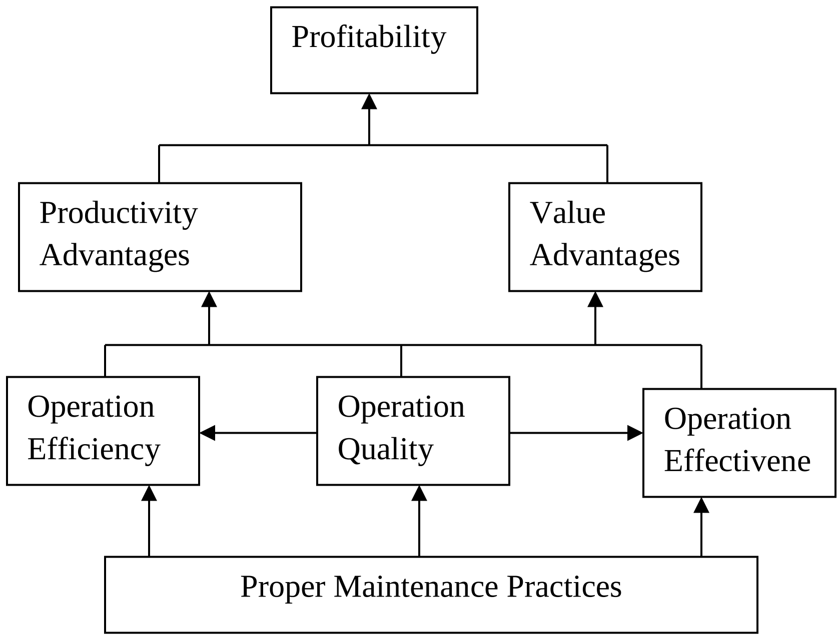

Figure 2.1: Impact of proper maintenance practices on companies' competitive advantages (Alsyouf, 2007).

Maintenance action requires some sets of important inputs e.g. manpower (labor), tools, equipment, management, spare parts and information (Blanchard, 2004).

2.4.1. Maintenance and Production

(Alsyouf, 2007) Affirm that the main task of production is to produce goods/ products. Nevertheless, efficient maintenance policy influences production capacity of machine used for producing these products. Maintenance therefore can be considered as an organizational function that functions in parallel with production (Ben-Daya & Duffuaa, 1995). While reiterating that production produce product, the authors also express that maintenance produces the capacity for production. Thus, it can be said that maintenance affects production by increasing production capacity while also controlling the output quantity and quality.

Maintenance role in accomplishing production objectives has already been pointed out in literatures, much remain to be done in order to integrate maintenance and production because in most models, maintenance is viewed as a limiting constraint and the question is how to meet the production master schedule under maintenance constraint (Ben-Daya & Duffuaa, 1995). Thus, the integration of maintenance and production has to be based on a clear understanding of their relationship. Maintenance affects production by increasing production capacity and controlling the quality and quantity of output. This is shown in the figure 2.2.

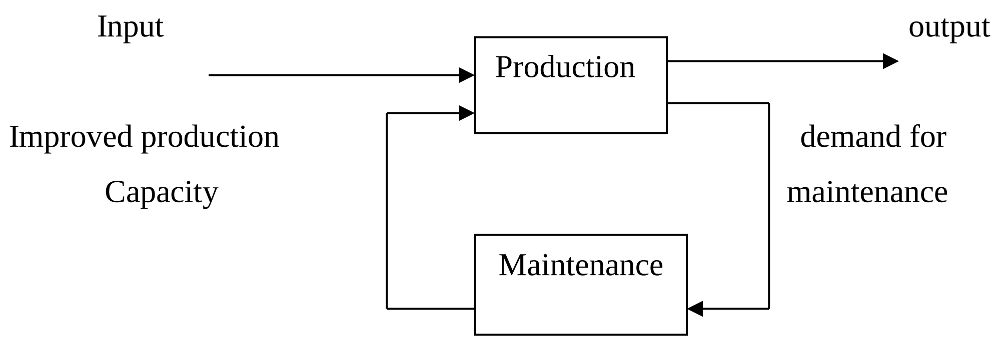

Figure 2.2. Production - Maintenance Relationship (Gits, 1994)

2.4.2. Maintenance and Quality

Company's profitability however cannot be achieved without sustained product quality. Quality has been recognized as the main edge for competitiveness and long-term profitability in modern day global economy (Madu, 2000). Thus, maintenance role in this endeavor cannot be over emphasized.

In general machines/ equipments which lack maintenance and fails periodically experiences speed losses or lack precision, and hence tend to produce defects. Such equipment often drives production processes out of control (Arca & Prado, 2008). Thus, a process that is out of control is bound to produce defective products, and at the same time increasing production cost which amounts to less profitability, thereby putting organizational survival at risk. This statement, demonstrates a strong link between equipment maintenance and product quality.

2.4.3. Maintenance and Productivity

Evaluating maintenance profitability, the impact on other working areas is also measured (e.g. by affirming maintenance role in machine life cycle profit). Maintenance improvements in general aim at reducing cost of operation and improving product quality, productivity, thus, the cost effectiveness of each improvement action may well be examined through evaluating the relevant cost constraint before and after improvements, a survey performed (Alsyouf , 2004) showed that 70 percent of the respondents considered maintenance as a cost center. Many studies have emphasized the role of maintenance in improving performance and profitability of manufacturing processes. (Al- Najjar & Alsyouf, 2004).

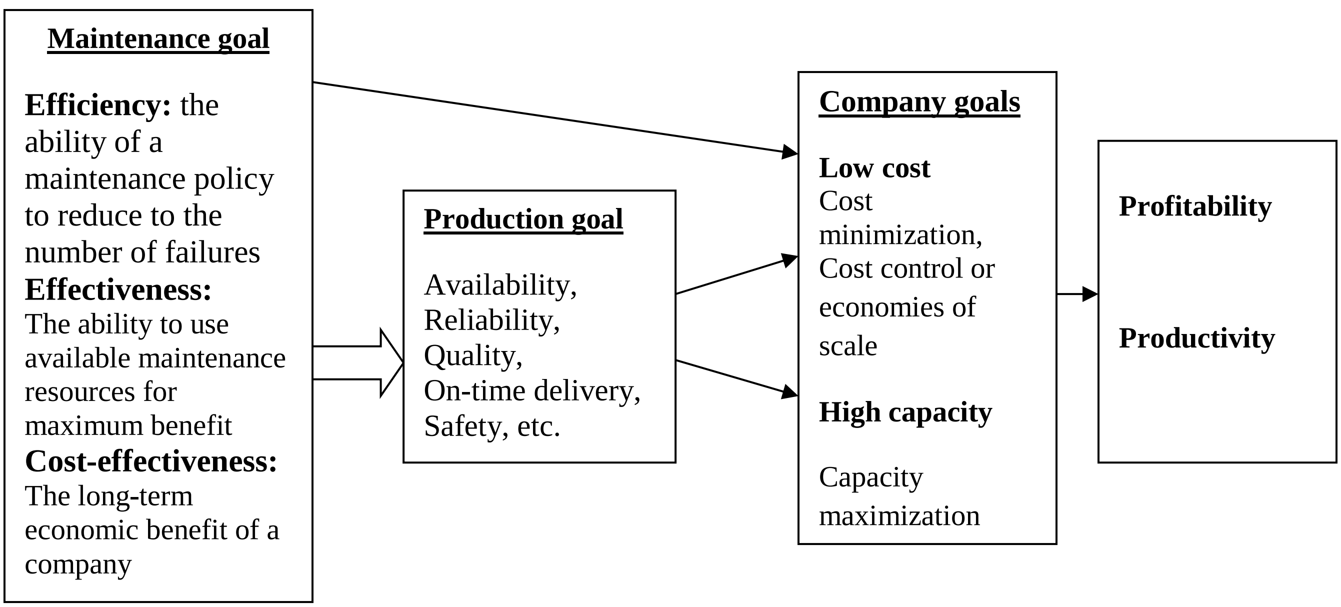

Figure 2.3. Connection between maintenance with profitability and productivity (Kans, 2008)

2.5. Maintenance Philosophy

Maintenance is classified into two major areas, i.e. Preventive maintenance all planned maintenance actions e.g. periodic inspection, condition monitoring etc. while Corrective maintenance includes all unplanned maintenance actions to restore failure (Blanchard, 2004).

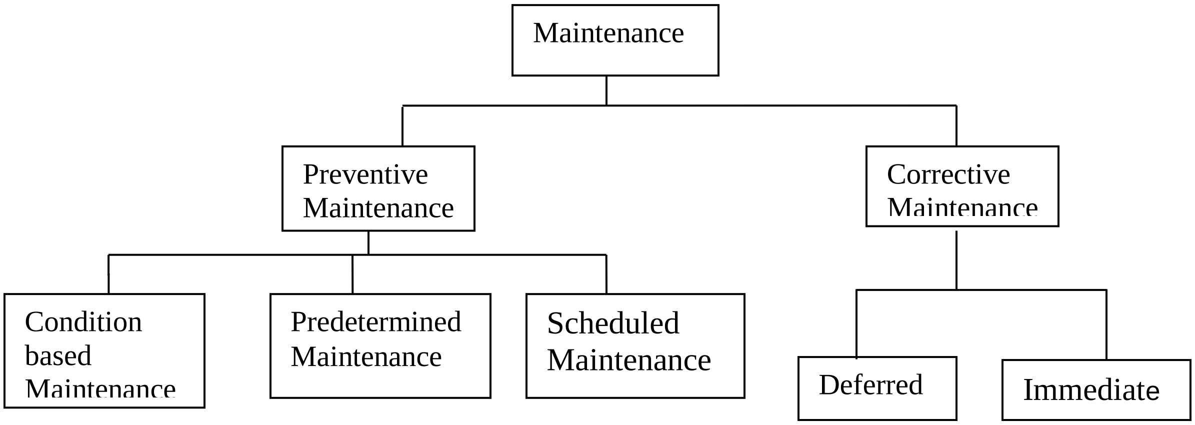

Figure 2.4. Overview of different maintenance approaches (Alsyouf, 2009)

a. Corrective Maintenance

It is a maintenance which is carried out after fault recognition and intended to put an item into a state in which it can perform a required function.

This management type is simple and straightforward, "fix it when it breaks, i.e. the things are fixed either after failure or during failure. This maintenance type is emergency, repair, unscheduled and remedial tasks. This method has been a major part of the maintenance operations since the first manufacturing plant was built, and it sounds reasonable on the surface. But it is actually a no-maintenance approach of management. It is also the most expensive one due to high machine downtime, low production availability; high overtime labor costs and high spare parts inventory cost (Devaraj Naik & Pradeep , 2016) (Alsyouf, 2004). The corrective technique does not take any maintenance action until equipment failure. This maintenance management philosophy is rarely used altogether without any preventive tasks (i.e. lubrication and adjustments). Still, in a corrective environment, the equipment are not rebuilt nor repaired in greater extent until it fails to operate.

b. Preventive Maintenance

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

The definition of preventive maintenance from the European standard (Parida, 2007) is presented as: "Maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item." (Obamwonyi, Martyn, & Aimienrovbiye, 2010).

Preventive maintenance can, according to the standard be divided into three divisions:

I. Scheduled Maintenance

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

II. Predetermined Maintenance/ Time Based Maintenance (TBM)

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

III. Condition Based Maintenance/ Predictive Maintenance

The term of predictive maintenance is defined as "Condition based maintenance carried out following a forecast derived from the analysis and evaluation of significant parameters of the condition of the item." Maintenance improvement strategy is presented which has been applied in a number of companies, with each of its elements tested for individual effectiveness and for its contribution to the whole program (platfoot, 1997).

2.6. Maintenance Approach

Various concepts have been developed to increase the effectiveness of maintenance and focus on the maintenance activities. Here, some examples are described including Reliability Centered Maintenance, RCM, Total Productive Maintenance, TPM and Lean Maintenance.

2.6.1. Reliability Centered Maintenance (RCM)

Reliability centered maintenance (RCM) is a process that determines what must be done to ensure that any plant asset continues to function in the desired manner within its present operating context. RCM is a systematic approach used to evaluate a facility's equipment and resources to best mate the two and result in a high degree of facility reliability and cost-effectiveness. RCM is highly reliant on predictive maintenance but also recognizes that maintenance activities on equipment that is inexpensive and unimportant to facility reliability may best be left to a reactive maintenance approach.

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.

RCM is applied by asking seven basic questions about the asset or system reviewed: (Moubray, 1997)

i. What are the functions and associated performance standards of the asset in its present operating context?
ii. In what way does it fail to fulfill its functions?
iii. What causes each functional failure?
iv. What happens when each failure occurs?
v. In what way does each failure matter?
vi. What can be done to predict or prevent each failure?
vii. What should be done if a suitable proactive task cannot be found?

Reliability-Centered Maintenance (RCM) is the optimum mix of reactive, time- or interval-based, condition-based, and proactive maintenance practices (Brauer & Brauer, 1987). These principal maintenance strategies, rather than being applied independently, are integrated to take advantage of their respective strengths in order to maximize facility and equipment reliability while minimizing life-cycle costs.

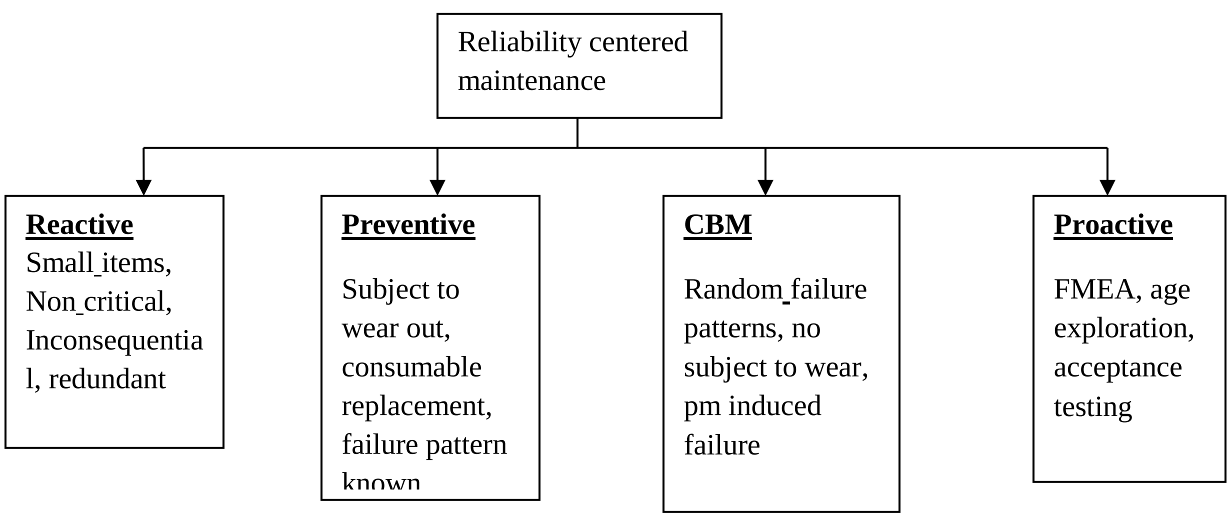

Figure 2.5. RCM Components (Devaraj Naik & Pradeep , 2016)

The RCM warrants significant improvements in the maintenance functions performance, and also an increase in reliability and availability of equipments. It permits the definition of a maintenance planning in a structured form (De- Queiroz & Alvares, 2008). Reliability centered maintenance (RCM) is a method for maintenance planning developed within the aircraft industry and later adapted to several other industries and military branches. This paper presents a structured approach to RCM, and discusses the various steps in the approach (Rausand & Vatn, 2008). The other paper describes the application of reliability-centered maintenance methodology to the development of maintenance plan for a steam-process plant. The main objective of reliability-centered maintenance is the cost-effective maintenance of the plant components inherent reliability value. The process-steam plant consists of fire-tube boiler, steam distribution, dryer, feed-water pump and process heater. Within this context, a maintenance program for the plant is carried out supported this reliability-centered maintenance concept (Afefy, 2010).

Failure mode effect analysis

The FMECA is a design tool used to systematically analyze postulated component failures and identify the resultant effects on system operations. The analysis is sometimes characterized as consisting of two sub-analyses, the first being the failure modes and effects analysis (FMEA), and the second, the criticality analysis (CA) (De- Queiroz & Alvares, 2008). Successful development of a FMEA requires that the analyst include all significant failure modes for each contributing element or part in the system. The purpose of the FMEA is to identify the critical components and prioritize equipment requires understanding the cause of failure to eliminate or reduce failures, starting with the highest priority ones. In FMEA, failures are prioritized according to answering the seven questions.

2.6.2. Comparisons of Maintenance Approach

Different maintenance systems are integrated to take advantage of their individual strengths, rather than being applied independently, so as to maximize facility and instrumentality irresponsibleness while minimizing life-cycle prices. Total productive maintenance (TPM), total maintenance assurance, preventive maintenance, reliability centered maintenance (RCM), and many different innovative approaches to maintenance issues all aim at enhancing the effectiveness of machines to ultimately improve productivity.

Table 2.1: Comparisons of Maintenance Approaches (Deepak & Jagathy, 2013)

Variables	Descriptions	Benefits	Shortcoming
Reactive	Fix or replace a device, only after failure. Suitable for non-critical and low cost equipment.	Low cost/resources required. Little time, effort or expense for maintenance until absolutely necessary.	Potential safety hazards and increased costs due to unplanned maintenance and associated downtime, overtime, spare parts and secondary damage.
Preventative	Scheduling maintenance activities based on defined time intervals. It is assumed that equipment condition is directly related to time or use.	Reduces reactive maintenance and provides a structure to maintenance actions. Flexible, energy savings, cost savings over reactive.	Does not eliminate unexpected equipment problems. Unneeded maintenance performed regardless of condition. Wastes resources/labor and results in large inventories.
Predictive	Assesses the equipment health through diagnostics testing and/or on-line monitoring to find and isolate the source of equipment problems.	Predicts when a device is likely to fail, minimizing the risk of random failure. Directs actions aimed at failure root causes as opposed to faults or machine wear conditions. Increased availability, quality, and safety.	High investment in diagnostic equipment and training. Results in being proactive in areas which have little effect on the plant's operation.
Reliability Centered Maintenance	A framework that defines a complete maintenance regime aimed at ensuring assets continues to perform their required function in the current operating context.	Increases the overall reliability of a plant by only undertaking maintenance on those components which actually affect the operation. Greater efficiencies and lower costs with fewer overhauls. Greater understanding of current risk levels.	The analysis can be time consuming, inflexible and difficult to initiate with significant start-up cost and training required.
Total Productive Maintenance	Improving availability through better utilization of maintenance and production resources. Critical adjunct to "lean".	Improves employee maintenance awareness and responsibility to improve equipment availability.	Primarily designed for a manufacturing environment to achieve: zero product defects, zero equipment unplanned failures and zero accidents.

2.7. Maintenance Management

Like in any other area of technology, management plays an important role in maintenance activity. Procedures and strategy are normally derived from maintenance management for all maintenance-related activities in addition to exercising required management and technical control of maintenance programs.

Management surveys show that the average productivity of maintenance employee is between 25 to 35% (Wireman, 1990). This means that a craftsman has less than 3 hours of productive time per 8 hour shift, due to poor maintenance management (Wireman, 1990). It is normally important that the manufacturing or production companies identify, define and communicate the maintenance strategies as business strategies are communicated to other business companies. With connection to the maintenance practices and procedures, maintenance management process has two parts; the first one is Effectiveness analysis which mainly deals with detecting the most important problems and potential solutions and the second is efficiency analysis which deals with identification of the suitable procedures.

2.7.1. 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.

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.

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 (Wireman, 1990).

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 is 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 contains the milestone dates for each maintenance job being performed and the number of man power allocated to breakdown, repair, and 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 work plan, status of the work order, scheduling of the work when resources are available for completing the work (Kelly, 1984).

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) (Blanchard, 2004). Knowing this helps to determine the staffing requirement for the craft group.

2.8. Maintenance Organization

According to (Kelly, 1984) maintenance organization consists of three essential and interconnected components, i.e. Resources, administration and work planning and control system.

Resources – includes personnel, tools/ equipments, spare parts, composition etc.

Administration – hierarchy of authority and responsibility for deciding what, how and when work should be done.

Work planning and control system – mechanism for planning and scheduling work and feedback information needed if maintenance effect is to be properly directed towards its defined objectives.

Further express that in most cases the problem often faced with maintenance organization is achieving the optimum balance between plant availability and maintenance resources utilization (Attia, 2006). Maintenance organization may take an infinite number of forms, leading to the best been determined by systematic consideration of factors like maintenance workload, unavailability cost, plant location, amount of emergency work, production organization and maintenance resources.

2.8.1. Objectives of Maintenance Organization

The objective of a maintenance organization lies in the ability to match maintenance resources to the maintenance workload aiming at the task of achieving and sustaining optimum availability. According to (Kelly, 1984) maintenance organization need continuous modification so as to respond to the changing requirements of maintenance and production system being because of its continuous evolving nature. A maintenance organization characteristic includes;

A. Maximizing production and ensuring equipment availability at a lower cost with higher quality.
B. Optimizing available maintenance resources
C. Gathering of necessary costs information associated with maintenance (e.g. labor cost, material cost, tool/ equipment cost etc)
D. Employing ways of decreasing expenses associated with maintenance and operation by identifying and implementing cost reduction.

2.9. Maintenance Performance Measurement

An organization always can spend considerable resources and time for measuring the performance and to assess the success of the organization. Performance measurement literature emphasizes the importance of maintaining relevant measures that continue to reflect the issues of importance to the business (Lynch & Cross, 1991).

However, most of the organizations pay little or no attention to integrating the performance measurement system with their organizational hierarchical levels and the different measurement criteria linked to the external and internal stakeholders as well as the operational process (Parida, 2007). In addition, not enough importance is given to the external and internal effectiveness to achieve total maintenance effectiveness for the organization. To be able to measure and improve performance of a process there should be existing current performance as a benchmark, so a set of equations and various types of approaches are involved in measuring the effectiveness and efficiency of the maintenance performance in the organization with the main aim of persuade maintenance staff to think of appropriate maintenance improvement strategies over the past experienced one.

2.9.1. Maintenance Cost

Maintenance cost or maintenance related costs in general are usually divided into direct and indirect cost without putting maintenance savings and profit into consideration (Al- Najjar & Alsyouf, 2004). Direct and indirect costs according include cost that are connected with in-house and outhouse (outsourcing) maintenance activities. (Al- Najjar & Alsyouf, 2004) Further refer to direct maintenance costs as costs associated directly to the maintenance activities, which include the internal costs that are required to carry out the maintenance functions e.g. labor, tools, spare parts, training etc. and other maintenance expenses that are directly related.

Indirect costs on the other hand includes all costs that are indirectly related or associated with maintenance, which can be attributed to issues like profit loss due to production losses during planned and unplanned stoppages, customer losses, reputation and consequently loss of market share as a result of maintenance related factors (Andrew & Moss, 2002). In addition, indirect maintenance costs includes performance inefficiency costs due to short stoppages and reduced speed, poor quality cost due to maintenance deficiency, idle fixed cost resources e.g. idle machine and idle worker costs during breakdowns, delivery delays penalty cost as a result of unplanned down time, assurance claim from dissatisfied customers as a result of maintenance related poor quality.

2.9.2. Overall Equipment Effectiveness

Overall equipment effectiveness (OEE) is a quantitative metric that has been increasingly used in manufactory systems for controlling and monitoring the productivity of production equipment, and also as an indicator and driver of process and performance improvements (Tsarouhas, 2013). The maintenance performance indicators are a measure of equipment availability, performance rate and quality rate. OEE addresses all losses caused by equipment faults, and many companies recognize the important role OEE plays in determining bottom-line results. The OEE calculation is used as an index for measuring maintenance performance. The model is organized in a structured and systematic way because it starts with the general elements such as quality, productivity and availability then examines the low-level maintenance losses such as reduced speed and defects (Muchiri & Pintelon, 2008). An advantage of OEE is that it provides a benchmark from which to start a maintenance initiative by providing one simple figure from three functional and important areas.

However, OEE, on its own, is not comparable for the brewery industry as it is difficult to examine slow running equipment. Therefore, a derivative of OEE was used to determine "availability, performance and quality rate".

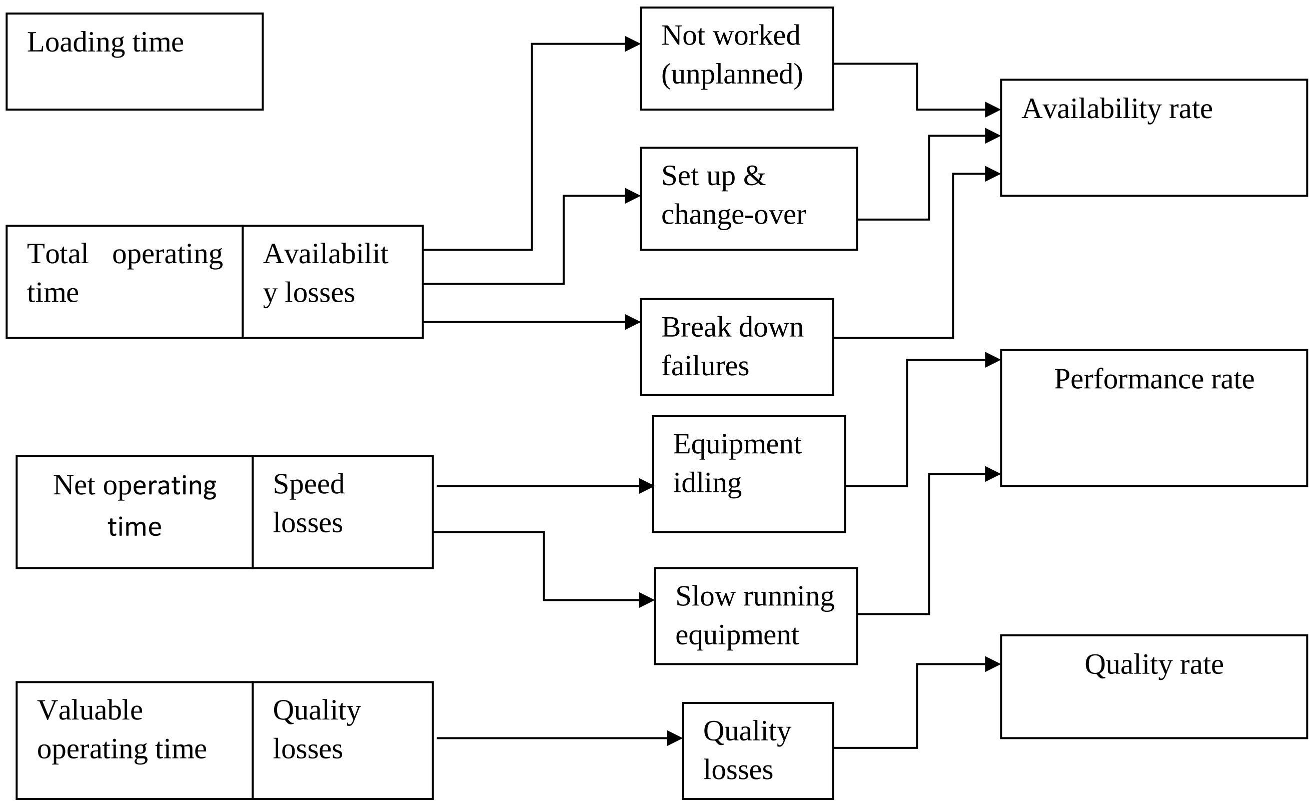

Fig 2.6 Maintenance Metric OEE (Tsarouhas, 2013)

The first three losses are known as downtime losses and are used to calculate the availability, A, of equipment, and is defined as:

Availability= (Loading time – Downtime)/Loading time……………………………………..2.1

Loading time is the time that the machine is supposed to be scheduled.

Downtime is a period during which equipment or a machine is not functional.

The fourth and fifth losses are a speed loss, which determine the performance efficiency, PE, of equipment and is defined as:
Performance efficiency = (Processed amount * Actual cycle time)/Operating time…………..2.2

Process amount is the quantity of product which is used for production of the output.

Actual cycle time is the actual time it takes for one machine to complete all of its operations.

Operating time is a period during which a system is working in a manner acceptable to its operator or user.

The final losses are considered to be losses due to quality defects, i.e. scrap, rework and start-up losses, defining as the quality rate, QR, and is defined as:
Quality rate = (Processed amount - Defect amount)/ Processed amount…………………….2.3

Defect amount is the quantity of product which is not used for production.

The three components above contribute to the determination of indicator OEE that globally expresses the production line effectiveness, and is defined as:
OEE= Availability* Productivity efficiency* Quality rate= A * PE * QR

The standards of 90% availability, 95% performance efficiency and 99% rate of quality (Levitt, 1996). An overall 85% benchmark OEE is considered as world-class performance. For continuous discrete processes, the OEE should be higher to 90%, whereas continuous stream process industries should have OEE values of 95% or better (Hanssen, 2002).

2.10. Literature Summary and Gap

The objective of this section is to investigate current best practice maintenance strategies in order to benchmark the effectiveness of DBSC current maintenance scheme. The research aims to identify gaps in current maintenance approach and to provide practical insights and recommendations to improve and optimize maintenance strategy based on case studies in related industries.

The following literatures which are extracted from different authors are important to have better understanding on maintenance system, and were help to identify the gap easily.

2.10.1. Literature summary

Table 2.2. Summary of Literatures

No	Literatures	Objective	Method	Finding
1	Maletic et al., 2012	To examine the role of maintenance in improving company's competitiveness and profitability	Survey collected from a Slovenian textile company and CBM	around 3 % of additional profit could be generated at weaving machine,
2	Alsyouf, 2009	To investigate the maintenance practices that are used in Swedish industry	Survey within Swedish firms, (TPM) & (RCM)	the role of maintenance is not highly recognized
3	European Committee for Standardization CEN., 2006	To gives a clear indication of how important a maintenance strategy is	Survey and questionnaire	Considers the most suitable type of maintenance, workforce, time and place for achieving the maintenance objectives
4	Afefy,2010	Cost-effective maintenance of the plant components inherent reliability value	RCM	22.17% of the annual spare parts cost are saved when proposed preventive maintenance planning
5	Ömür et al., 2009	To improve the overall efficiency of the system	CBM	Identifying things on reducing maintenance costs and increases efficiency as well on availability
6	Kelly, 1984	To have planning and scheduling on maintenance principles	Survey and questionnaire	A brief breakdown of each maintenance principles to plan and schedule
7	Shelke et al., 2001	To show effect of implementing TPM in organization; in Brewery company	TPM	Availability improved with average improvement of 2.25%

8	Tsarouhas, 2013	Investigates the relationship between the factory management and the operation	Descriptive Statistics at machine & OEE	PE and QR should be improved immediately to optimize the productivity and the efficiency
9	Olayinka et al., 2000	Examine the production performance of a beverage manufacturing plant	TPM	Increased OEE by 50%
10	Melesse et al., 2012	To evaluate the contribution of TPM	TPM	Increase equipments availability
11	Misikir 2004	To examine how proper maintenance management improves the productivity	TPM	CPMM is developed
12	Meseret 2007	Increase productivity by identifying the main problems	TPM	Find the causes of breakdown and minimize them

2.10.2. Literature Gaps

Literature search identified different research works that have dealt with maintenance in relation to company's competitiveness and profitability. Most researches have done the problem associated to maintenance and in order to solve those maintenance problems they focused on different maintenance approaches using TPM, PM, CBM, RCM. Despite that the importance of maintenance impact on company's business is emphasized, literature search showed that no much previous works have investigated maintenance impact on company's productivity on the Brewery Company in Ethiopia. Therefore, this paper seeks to explore the role of maintenance in improving company's competitiveness and reliability to overcome the critical concern to productivity in the Dashen Brewery Company.

In this thesis the impacts of maintenance problems and their effects on the productivity on the brewery share company were studied by using RCM and gave a better solution in giving good change to the maintenance problems. Because RCM is a decision making tool, so operations and maintenance program can benefit both the processes involved in the decision making, good benefits and outcomes, which result in the changes to maintenance and operations programs rather than other approaches.

TPM has been demonstrated as beneficial in reducing equipment breakdowns, minimizing idling and minor stops (indispensable in unmanned plants), lessening quality defects and claims, boosting productivity, trimming labor and costs, shrinking inventory, cutting accidents, and promoting employee involvement. TPM has found acceptance in manufacturing industries, whereas, in the process industries the application has been limited (Deepak & Jagathy, 2013).

The act of performing the RCM method provides a benefit in promoting better cooperation among all of those involved in the process. The method raises awareness of the function of the system involved, the consequences of failure of the function and the economics of operating and maintaining them. RCM provides a means for communication, and hence a possible bridge over the gap between theory and practice (Moubray, 1997). By using this bridge, the statisticians and operations researchers may get help to establish more realistic models and methods, and transform these into practical tools for the maintenance practitioners. Application of their models in a real situation will certainly be an incentive to improve their research.

Therefore, the aims of RCM are to improve reliability and optimize the cost effectiveness of maintenance activities. When performed effectively it were result in the elimination of unnecessary maintenance tasks and the introduction of measures to address and deficiencies in maintenance programs.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.1. Research Method

This study has been used two kinds of sources to collect information, primary and secondary sources. Primary sources focused on information which helps to have the entire understanding of the study through different techniques such as interviews, questionnaires, & discussions. Whereas secondary sources of information related with the study to have detail understanding with the supportive documents and reports.

To make effective the collection has been used two methods, quantitative and qualitative method. Quantitative implies that the way of collections which can be described, counted, and measured in certain amount. Thus, the result can be expressed in number and can be formulated. But qualitative method has been a different way of expression in reverse that can't be expressed in figure.

3.1.1. Data Collection Method

The methodology followed to approach with reliable results, collecting data on the current maintenance system, maintenance organization, production constraints. The downtime, critical machinery breakage, lack of technician's training were believed to indicate the appropriate maintenance functions various survey methods used to assess the current situation of the company.

Primary Data

Primary data defined as data collected by a program of observation qualitative and quantitative method either separately or in combination to meet the specific objective of the research.

a. Physical observation/case study

Physical observations are carried out to see the maintenance system on some critical equipment or working stations. From the physical observation of the maintenance system, it is understood that different sections of the factory follow different maintenance processes.

b. Survey questionnaires

The survey questionnaires for assessing the maintenance system in the company are designed. The questionnaires were prepared for the management, maintenance department and production department. Likert scale data was obtained from a structured questionnaire response which is distributed for the sample size. In the survey, 69 employees were targeted to answer a paper questionnaire. This number was chosen out of a total of 80 employees who are working under the maintenance departments. The respond rate was about 86.9% (60 respondents) in total. Department and division heads, Line supervisors, chief engineers and foremen and some workers (operators) were selected to response the questionnaire. The questionnaire used in this study consists of seven main parts and 49 main questions comprising a total of 3 pages. The questionnaires contained five types of answers i.e. strongly agree, agree undecided, disagree and strongly disagree. According to the table the reliability and validity were checked, and the value of Cronbach's Alpha is 0.892 which is greater than 0.7. Therefore it's acceptable.

Table 3.1 Reliability Analysis and Checking

Case Processing Summary

		N	%
Cases	Valid	20	100.0
	Excluded	0	.0
	Total	20	100.0

Reliability Statistics

Cronbach's Alpha	N of Items
0.892	49

Secondary Data

Secondary data is the information that the organization has or has been published and is accessible through electronic source coming from outside the organization. This information was valuable to this research to allow seeing the relationship existing currently in Dashen Brewery.

c. Literature survey

To be familiar with the concepts of maintenance function, maintenance system and key performance indicators, improvement, literature review was carried out. Journal articles were also reviewed to reinforce the current maintenance practices of the factory.

d. Document retrieval

During document analysis the researcher has gone through company profile, factory organization chart, maintenance organization chart, work request books, monthly and annual performance reports and others relevant documents and formats of the company.

3.1.2. Data Analysis

In data analysis part, following the method that used in data collection analysis has been shown clear image of the existing system for the ease of finding an appropriate solution. Both data from existing company and from questionnaire were analyzed by means of computer software i.e. Microsoft Excel 2010, Pareto and Statistical Package for Social Sciences (SPSS). Finally the data were compared with the written approach in literature survey for finding new and possible maintenance system approaches.

3.2. Research Framework

This research were used the case studies from DBSC whereby quantitative and qualitative data are collected and analyzed. The general flow plan of the methodology is visualized in figure, which gives an understanding on how the method suits the stated objectives.

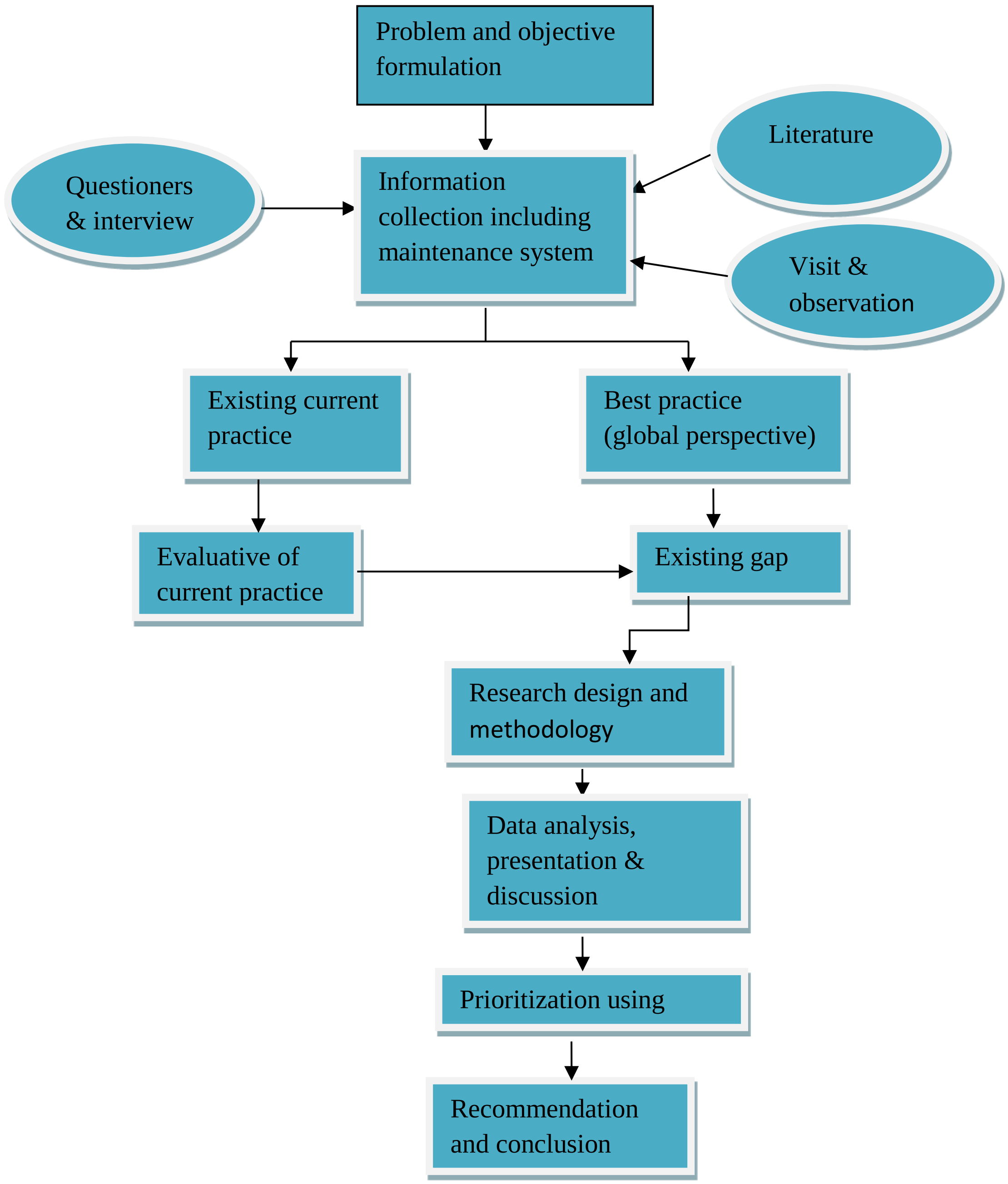

Figure 3.1. Research framework design

3.3. Ethical Consideration

The study considered some ethical issues. This are the respondent experts and others has the right to respond or not, the respondent experts and others has the right to participate or not, the study has done to inform respondents the purpose of the questioner and the study considers the confidentiality of the response by not asking to state name. While conducting the study, emerging ethical issues has been considered and given attention. Before attempt to collect the data official permission was obtained from DBSC.

CHAPTER FOUR

DATA ANALYSIS AND DISCUSSION

4.1. Introduction

For the purpose of gap analysis a questionnaire was prepared, in order to evaluate importance and agreement of different maintenance practices in the observed company. To measure maintenance practices, respondents were asked to report the level of importance and agreement considering seven different maintenance activities. The questionnaire was presented in the appendix. Respondents in this study were employees (N=60) from maintenance and production department, since maintenance is part of it. As regards the empirical examination a special form was prepared in order to obtain data, such as machine productivity, down time.

In this chapter, the data has been collected from DBSC and presented the main analysis of this study with respect to the problem formulation. Hence, the presented theories are used in relation with the empirical finding to analyze the current situation at the company.

4.1.1. Quantitative Data

The following table describes the frequency distribution of demographic variable of the respondents. Majorities of the respondents 30(50%) were in packing departments, 53(88.3%) were male and 39(65%) had marital status married.

Table 4.1: Frequency table for demographic variable

Demographic Variable		**Frequency**	**Percent**
Department	Utility	20	33.3
	Beer House	10	16.7
	Packaging	30	50.0
Gender	Female	7	11.7
	Male	53	88.3
Marital Status	Single	19	31.7
	Married	39	65.0
	Divorce	2	3.4

Maintenance Organization

This section describes the maintenance organization of employees in different department. Majority of the respondents 21(35%), 22(36.7%), 31(51.7%) and 30(50%) agreed on the overall structure of the maintenance organization seem to be logical to accomplish the work, the management encourage maintenance to meet the needs of production, maintenance technicians follow safety policies and procedures when they do their tasks and the industry support to continuous improvement efforts. Besides 18 (30%) were disagreed on the management support maintenance technicians and production operators to work together on problems.

Table 4.2: Frequency table for Maintenance Organization

Maintenance Organization		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The overall structure of the maintenance organization seem to be logical to accomplish the work in Dashen brewery S.C	Fi	9	11	12	21	7
	%	15.0	18.3	20.0	35.0	11.7
The management encourages maintenance to meet the needs of Production.	Fi	10	20	4	22	4
	%	16.7	33.3	6.7	36.7	6.7
The management support maintenance technicians and Production operators to work together on problems.	Fi	13	18	12	13	4
	%	21.7	30.0	20.0	21.7	6.7
Maintenance technicians follow safety policies and procedures when they do their tasks	Fi	4	4	13	31	8
	%	6.7	6.7	21.7	51.7	13.3
The industry support to continuous improvement efforts	Fi	6	8	8	30	8
	%	10.0	13.3	13.3	50.0	13.3

Training Programs within Maintenance

This section describes the training programs within maintenance in different department. Majority of the respondents 24(40%), 25(41.7%), 21(35%) and 22(36.5%) disagreed on training concerning on the provision of training new technologies are provided frequently to the maintenance craft employees at the company, scheduled training programs are given on maintenance, craftsmen take training to help themselves to do their jobs properly and the organization have low cost and accessible training facilities respectively. In addition, 22(36.7%) and 25(41.7%) were agreed on Maintenance craftspeople in the plant are properly skilled to do their jobs and the organization have well trained and experienced craftsmen respectively. Also 19(31.7%) and 40(66.7%) were neutral and strongly agreed on their familiar with the installed equipment of the company and they think the training programs are very important for effective maintenance respectively.

Table 4.3: Frequency table for training programs within maintenance

Training Programs within maintenance		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Training concerning new technologies are provided frequently to the operators at your Company	Fi	12	24	11	9	4
	%	20.0	40.0	18.3	15.0	6.7
Scheduled training programs are given on maintenance	Fi	14	25	10	8	3
	%	23.3	41.7	16.7	13.3	5.0
Maintenance operators in the plant are properly skilled to do their jobs.	Fi	4	14	12	22	8
	%	6.7	23.3	20.0	36.7	13.3
Operators take training to help themselves to do their jobs properly	Fi	12	21	15	10	2
	%	20.0	35.0	25.0	16.7	3.3
You are familiar with the installed equipment of the company	Fi	1	9	19	17	14
	%	1.7	15.0	31.7	28.3	23.3
You think training programs are very important for effective maintenance	Fi	2	4	1	13	40
	%	3.3	6.7	1.7	21.7	66.7
The organization have low cost and accessible training facilities	Fi	11	22	12	10	5
	%	18.3	36.7	20.0	16.7	8.3
The organization have well trained and experienced craftsmen	Fi	5	4	13	25	13
	%	8.3	6.7	21.7	41.7	21.7

Maintenance Planning and Scheduling

This section describes the maintenance planning and scheduling in different department. Majority of the respondents 25(41.7%), 19(31.7%), 38(63.3%), 24(40%), 26(43.3%), 29(48.3%) and 23(38.3%) agreed on the total amount of work orders have been delayed due to poor or incomplete plans, responsibility for planning the preventive work orders relies on maintenance planner, they set priorities for maintenance job tasks, the equipment are maintained within a short time when the equipment failed, when the maintenance job is completed, the craftsmen that performed the job reports the actual working time used material and downtime, they planned shutdowns for major repairs in advance and they have appropriate spare parts for maintenance respectively. At the reverse majorities 20(33.3%) were neutral on the industry have programs to evaluate the effectiveness of the maintenance that is carried out.

Table 4.4: Frequency table for Maintenance planning and scheduling

Maintenance planning and scheduling		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The total amount of work orders have been delayed due to poor or incomplete plans (previous year)	Fi	5	10	10	25	10
	%	8.3	16.7	16.7	41.7	16.7
Responsibility for planning the preventive work orders relies on maintenance planner	Fi	6	10	17	19	8
	%	10.0	16.7	28.3	31.7	13.3
The industry have programs to evaluate the effectiveness of the maintenance that is carried out	Fi	9	11	20	14	6
	%	15.0	18.3	33.3	23.3	10.0
You set priorities for maintenance job tasks	Fi	3	6	5	38	8
	%	5.0	10.0	8.3	63.3	13.3
The equipment are maintained within a short time when the equipment failed.	Fi	6	4	14	24	12
	%	10.0	6.7	23.3	40.0	20.0
When the maintenance job is completed, the craftsmen that performed the job reports the actual working time, used material, and downtime.	Fi	6	8	9	26	11
	%	10.0	13.3	15.0	43.3	18.3
You planned shutdowns for major repairs in advance	Fi	3	7	9	29	12
	%	5.0	11.7	15.0	48.3	20.0
You have appropriate spare parts for maintenance	Fi	4	10	14	23	9
	%	6.7	16.7	23.3	38.3	15.0

Preventive Maintenance

This section describes the preventive maintenance in different department. Majority of the respondents 25(41.7%), 24(40%), 28(46.7%), 17(28.3%), 26(43.3%), 25(41.7%), 26(43.3%) and 37(61.7%) agreed on the organization use work orders for preventive maintenance activities, The preventive maintenance program cover critical equipment, the operators help in cleaning equipment, the operators help in lubricating equipment’s, the operators help in adjusting equipment’s, the organization has track record how much it costs (Life Cycle Cost) to maintain equipment, the organization tries to prevent breakdowns and failures from recurring and the organization have a schedule for periodic preventive maintenance respectively. Majority of the respondents 23(38.3%), 21(35%) were disagreed on the maintenance program periodically review preventive maintenances for accuracy and training needs and the operators help inspection of equipment's respectively, 18 (30%) were neutral on the organization have an evaluation mechanism for the performance of preventive maintenance and 10 (30%) strongly disagreed on the organization has an inspection team to check the actual condition of equipment.

Table 4.5: Frequency table for Preventive Maintenance

Preventive Maintenance		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The organization use work orders for preventive maintenance activities	Fi	3	9	11	25	12
	%	5.0	15.0	18.3	41.7	20.0
The preventive maintenance program cover critical equipment	Fi	2	11	16	24	7
	%	3.3	18.3	26.7	40.0	11.7
The maintenance program periodically review preventive maintenances for accuracy and training needs	Fi	8	23	14	12	3
	%	13.3	38.3	23.3	20.0	5.0
The operators help in cleaning equipment	Fi	1	3	2	28	26
	%	1.7	5.0	3.3	46.7	43.3
The operators help in lubricating equipment's	Fi	8	12	12	17	11
	%	13.3	20.0	20.0	28.3	18.3
The operators help in adjusting equipment's	Fi	2	10	5	26	17
	%	3.3	16.7	8.3	43.3	28.3
The operators help inspection of equipment's	Fi	6	21	9	14	10
	%	10.0	35.0	15.0	23.3	16.7
The organization has track record how much it costs (Life Cycle Cost) to maintain equipment	Fi	5	10	11	25	9
	%	8.3	16.7	18.3	41.7	15.0
The organization tries to prevent breakdowns and failures from recurring	Fi	3	11	12	26	8
	%	5.0	18.3	20.0	43.3	13.3
The organization have an evaluation mechanism for the performance of preventive maintenance	Fi	5	16	18	17	4
	%	8.3	26.7	30.0	28.3	6.7
The organization have a schedule for periodic preventive maintenance	Fi	5	4	8	37	6
	%	8.3	6.7	13.3	61.7	10.0
The organization has an inspection team to check the actual condition of equipment.	Fi	18	10	15	13	4
	%	30.0	16.7	25.0	21.7	6.7

Maintenance Inventory and Purchasing

This section describes the maintenance inventory and purchasing in different department. Majority of the respondents 32(53.3%), 28(46.7%), 25(41.7%) and 32(53.3%) agreed on the control in the maintenance inventory of spare parts, indicator of maximum and minimum levels for specified stored materials, a permanent supplier of spare parts and the appropriate management system for spare parts respectively 28(46.7%) respondent were disagreed on availability of critical spare parts in the store.

Table 4.6: Frequency table for Maintenance Inventory and Purchasing

Maintenance Inventory and Purchasing		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
There is an availability of critical spare parts in the store	Fi	3	28	11	7	11
	%	5.0	47.7	18.3	11.7	18.3
There is a control in the maintenance inventory of spare parts	Fi	2	2	12	32	12
	%	3.3	3.3	20.0	53.3	20.0
There is an indicator of maximum and minimum levels for specified stored materials	Fi	5	5	15	28	7
	%	8.3	8.3	25.0	46.7	11.7
There is a permanent supplier of spare parts	Fi	5	7	13	25	10
	%	8.3	11.7	21.7	41.7	16.7
There is an appropriate management system for spare parts	Fi	3	3	10	32	12
	%	5.0	5.0	16.7	53.3	20.0

Reliability Engineering

This section describes the reliability engineering in different department. Majority of the respondents 17(28.3%), 28(46.7%), 19(31.7%) and 27(45%) agreed on failure analysis conducted by the use of an analysis tool such as fishbone, tree, five why's or Pareto, to assure accuracy and standardization for each analysis, the machines perform their required function for the specified time, they have a method which increases reliability of machines and The organization believe that improving maintenance could increase the reliability of production system respectively. And majorities 21(35%) were disagreed on the overall equipment evaluation calculated to monitor the condition of critical equipment.

Table 4.7: Frequency table for Reliability Engineering

Reliability Engineering		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
There is failure analysis conducted by the use of an analysis tool such as fishbone, tree, five why's or Pareto, to assure accuracy and standardization for each analysis	Fi	13	13	15	17	2
	%	21.7	21.7	25.0	28.3	3.3
There is overall equipment evaluation calculated to monitor the condition of critical equipment	Fi	7	21	18	10	4
	%	11.7	35.0	30.0	16.7	6.7
The machines perform their required function for the specified time	Fi	4	8	13	28	7
	%	6.7	13.3	21.7	46.7	11.7
You have a method which increases reliability of machines	Fi	11	15	12	19	3
	%	18.3	25.0	20.0	31.7	5.0
The organization believe that improving maintenance could increase the reliability of production system	Fi	3	5	3	27	22
	%	5.0	8.3	5.0	45.0	36.7

Production Efficiency

This section describes the Production Efficiency in different department. Majority of the respondents 29(48.3%), 29(48.3%), 27(45%) and 25(41.7%) agreed on the production focuses on maintenance practice, there is frequent machine downtime, machine downtime reduces designed or planned production capacity and in your brewery company unexpected maintenance cost happens highly respectively. And majorities of the respondent 38(63.3%) were strongly agreed on Stoppage of production has a huge impact on the organization.

Table 4.8: Frequency table for Production Efficiency

Production Efficiency		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The production focuses on maintenance practice	Fi	3	4	9	29	15
	%	5.0	6.7	15.0	48.3	25.0
Stoppage of production has a huge impact on the organization	Fi	3	0	2	17	38
	%	5.0	0	3.3	28.3	63.3
There is frequent machine downtime	Fi	2	5	8	29	16
	%	3.3	8.3	13.3	48.3	26.7

Machine downtime reduces designed or planned production capacity	Fi	2	1	1	27	29
	%	3.3	1.7	1.7	45.0	48.3
In your brewery company unexpected maintenance cost happens highly	Fi	2	5	10	25	18
	%	3.3	8.3	16.7	41.7	30.0

Summary

From the survey questionnaire result the contribution of the seven variables to the maintenance problems is as follows. For the questions given in maintenance organization majority of the respondents give a positive response that the company has a good overall structure of the maintenance organization but they have negative response about the management support consider maintenance activities. In the training programs within maintenance most of the respondents answer that trainings concerning new technologies are not provided frequently to the maintenance craft employees at the company and there is no scheduled training programs which are given on maintenance. For the questions given in maintenance planning and scheduling the response of most of the respondents agree on the responsibility for planning the preventive work orders relies on maintenance planner, they set priorities for maintenance job tasks and the equipment are maintained within a short time when the equipment failed. For preventive maintenance, large amount of the respondents replied that the company has no maintenance programs which periodically review preventive maintenances for accuracy and training needs, the operators don't help inspection of equipment and has no inspection team to check the actual condition of equipment. In the maintenance inventory and purchasing questions most of the respondents agreed on the control in the maintenance inventory of spare parts, but they didn't agree on prioritized critical components. Majority of the respondents for the questions given in reliability engineering agreed on almost all of the questions. In production efficiency questions the respondents answer that there is a frequent machine downtime which reduces designed or planned production capacity and in the company there is unexpected maintenance cost. From these results, the company faced with maintenance problems and reduced production efficiency due to lack of training programs, lack of preventive maintenance, lack of management support about maintenance activities and frequent machine downtimes.

4.1.2. Documentation Review

The data below were explained and support to know the existing condition of the company using documented records from previous years. Quantitative data covered the period from 2014 to 2016 from three departments, about machine down time status on previous years as per recorded data. Thus, selected necessary data are presented in the appendix part:

Packaging Machine Downtime, 2014

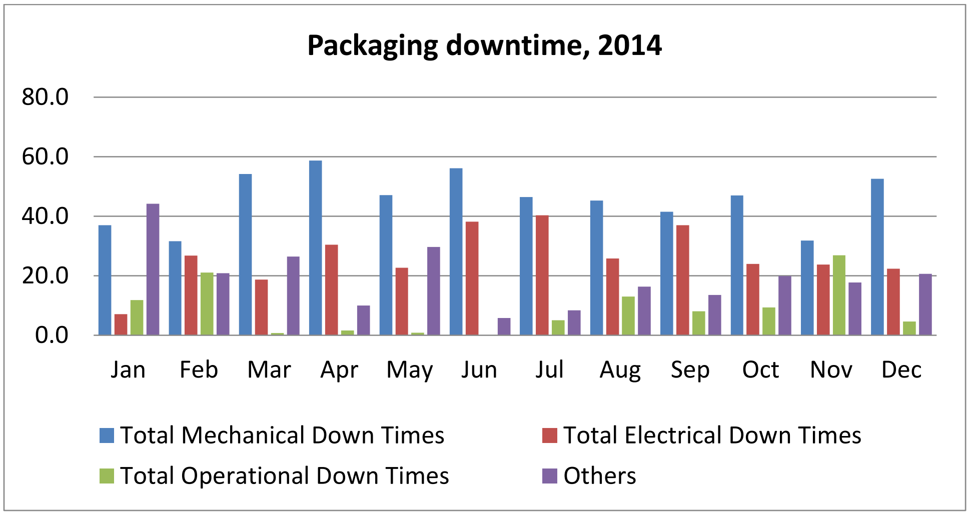

Figure 4.1. Downtime analysis on packaging, 2014

Figure 4.1 describes four down time status of packaging section in year 2014, the detail was explained below.

In each month of the year there are four types of down times with their down time result. From the chart, of each month down time status, mechanical down time, has scored highest percentage through the entire year. Other down times, Electrical, operational and others has shown less percentage compare with mechanical down time. In each month starting from Jan- Dec, down time for mechanical will keep increased up while down time for other three will go up and down through the entire year.

So in general on this year 2014, as per the detailed above, and can concluded that, of the four types of down time during operation time, Mechanical down time has highest percentage per each month than others throughout the year.

Packaging Machine Downtime, 2015

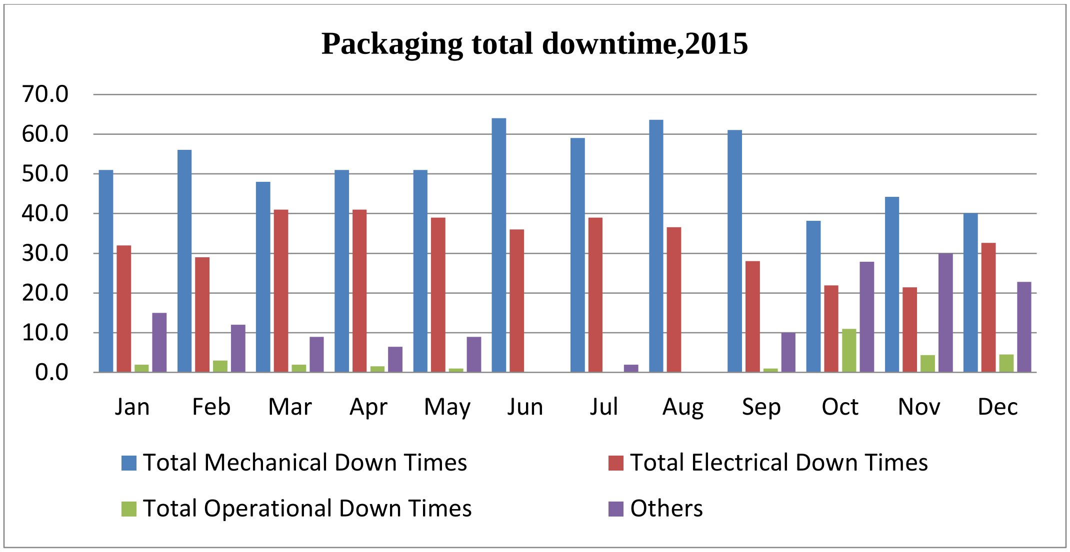

Figure 4.2.down time analysis on packaging, 2015

It can be observed from Figure 4.2 there are four types of down time status for year 2015 in packaging section.

Of the indicated down times in each month, mechanical, electrical, others, and operational down times show consistent increment through the entire year respectively. In each month of the year when goes through, the increment from month to month presents the same down times result. In all month of the year mechanical down time has highest percentage than the others. Of all down times in packaging section, mechanical down time has long waiting down time through the year. As the figure 4.2 show that, each month starting from Jan down time for mechanical stay highest while down times for others decreased.

Packaging Machine Downtime, 2016

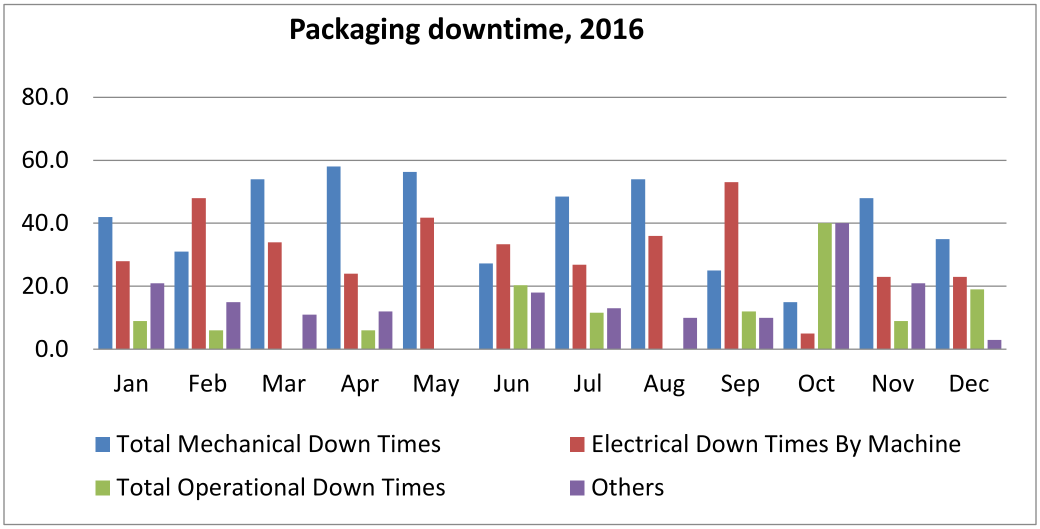

Figure 4.3. Down time analysis on packaging, 2016

The focus for the Figure 4.3 show that on down time analysis in packaging section in year 2016 with the below illustrations.

It can be seen that four of down time types show variety down time status percentage through each month of the year. However, of all them mechanical down time performs highest percentage through the entire. And electrical down time comes next to mechanical down time. The increment from month to month keep the trend with upward mechanical down time, electrical down time, operational down time, and others respectively.

And can concluded that in year 2016 the status for down times look like highest in mechanical down time, lowest in others and higher in electrical down times throughout the year. This indicates that reason for low productivity in this section is due to frequent mechanical down time. Even though other down times are available, mechanical down time keep continue high through each month.

Brew house Machine Downtime, 2014

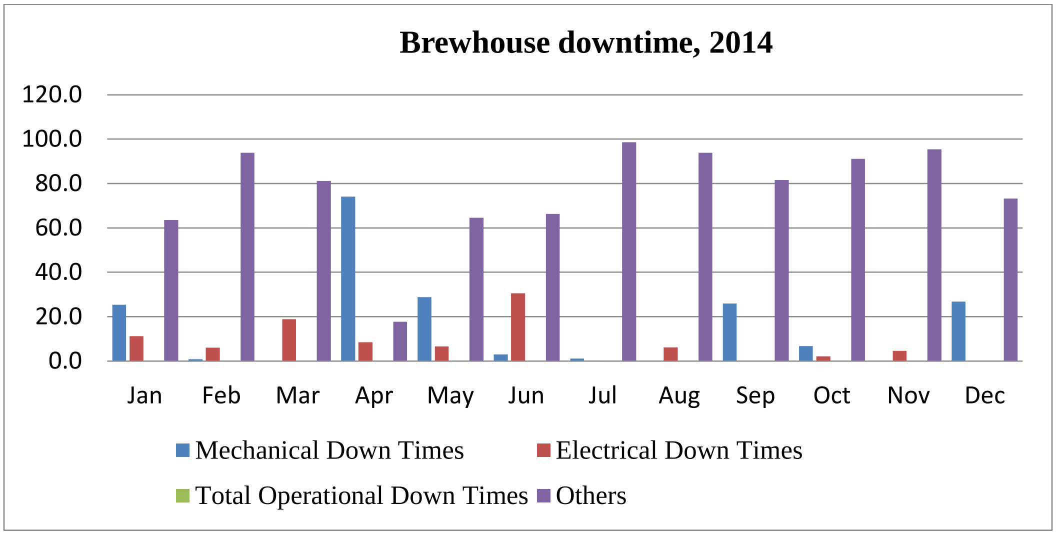

Figure 4.4. Downtime analysis on brew house, 2016

Brew house Machine Downtime, 2015

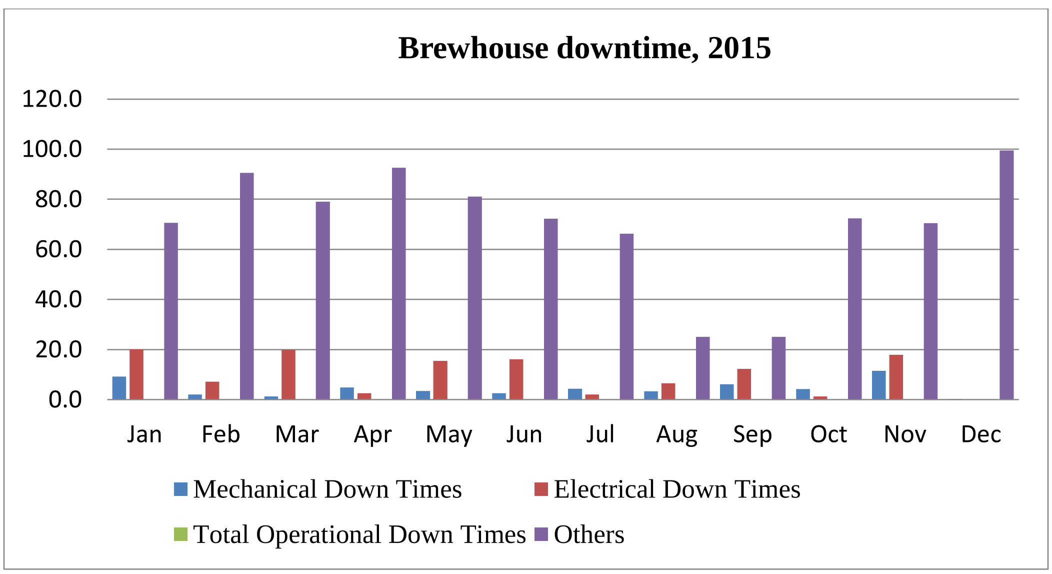

Figure 4.5. Downtime analysis on brew house, 2015

Brew house Machine Downtime, 2016

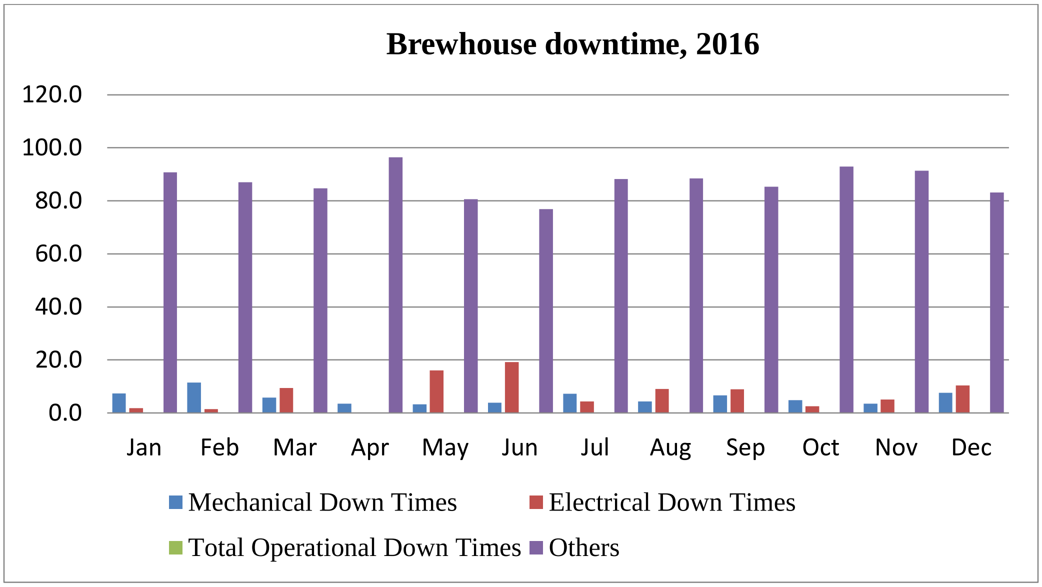

Figure 4.6. Downtime analysis on brew house, 2016

According to Figures 4.6 show that the recorded data the year from 2014-2016 included machine downtimes due to mechanical maintenance problems, electrical maintenance problems, operation problems such as enough bright beer, beer change, cooling problem, Filter bag change etc. and other problems such as power fluctuation, cleaning purpose and so on.

The result from Microsoft Excel for brew house section the total machine downtime due to maintenance problems shows that:

i. Mechanical down time problems, for total electrical machine downtimes, operational down time and others for the annual year 2014 is 16.05 %, 7.9 %, 0%, 76.7%, respectively.
ii. Mechanical down time problems, for total electrical machine downtimes, operational down time and others for the annual year 2015 is 4.42 %, 10.1 %, 0%, 70.3%, respectively.
iii. Mechanical down time problems, for total electrical machine downtimes, operational down time and others for the annual year 2016 is 5.81 %, 7.3 %, 0%, 87.1%, respectively.

Based on the above results the problems are due to others such as power fluctuation, cleaning purpose accounts higher percentage of machine downtimes. From this it can be concluded that machine downtimes due to this problems in brewing section reduces the production capacity of the industry.

Utility downtimes, 2014

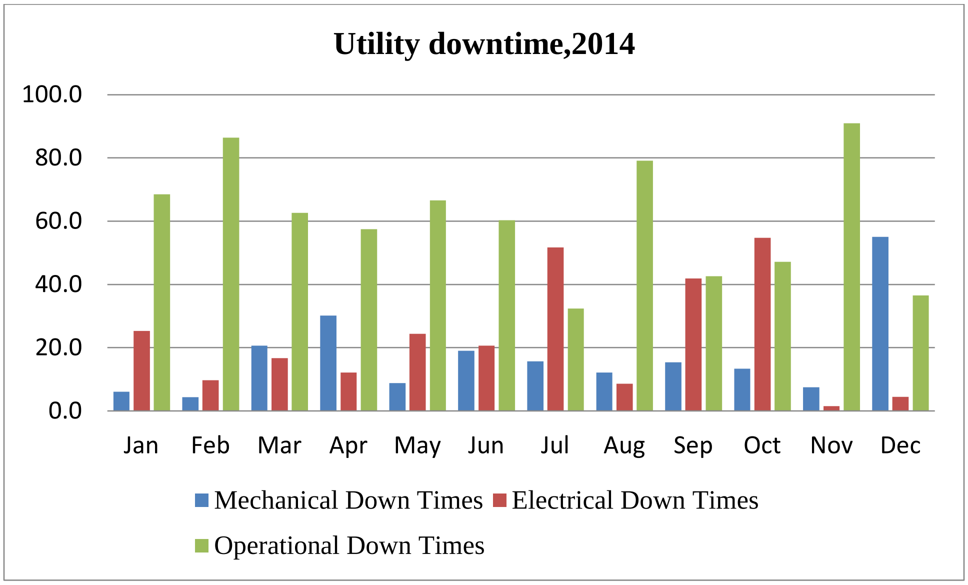

Figure 4.7. Down time analysis on utility, 2014

Utility down time, 2015

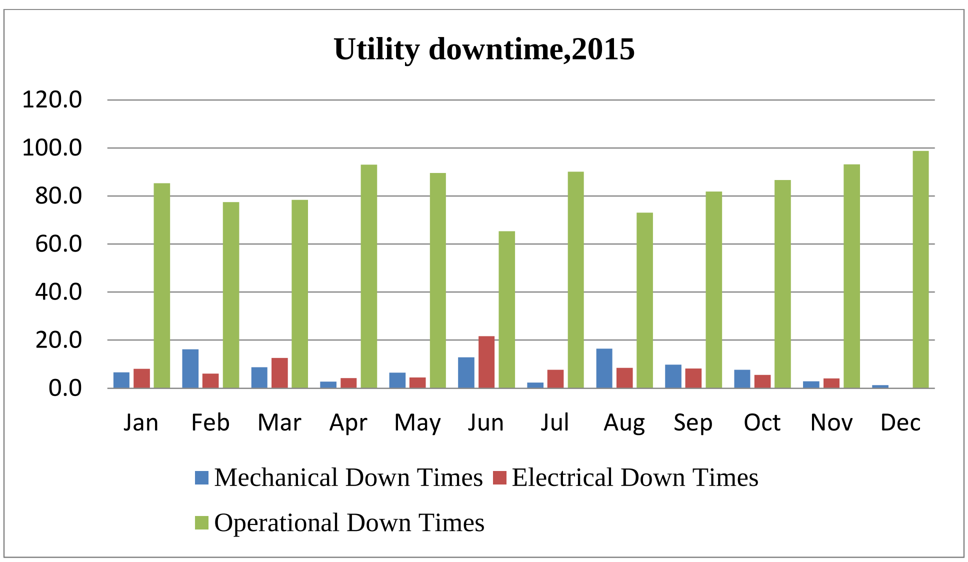

Figure 4.8. Downtime analysis on utility, 2015

Utility down time, 2016

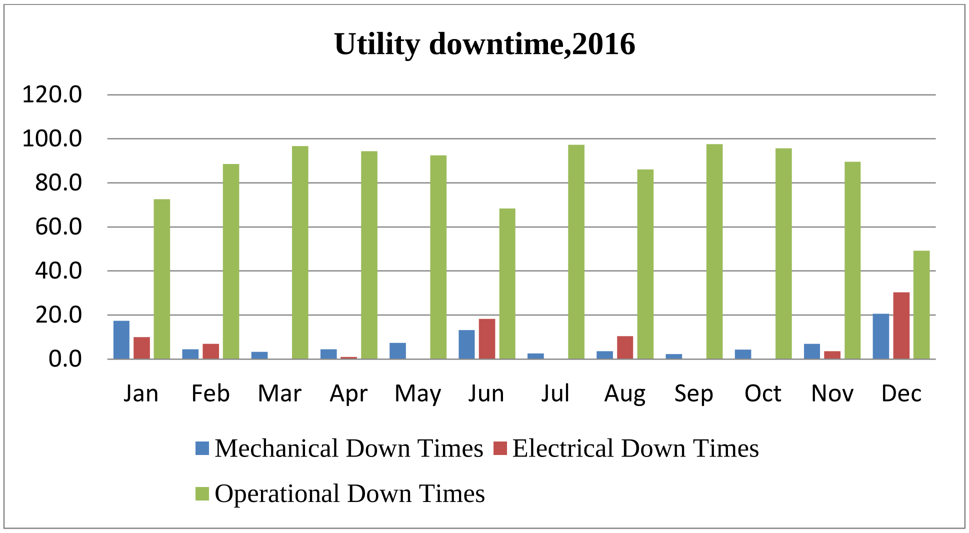

Figure 4.9. Downtime analysis on utility, 2016

Seeing as utility is one of the sections in the company provides air, CO_2, water and steam for the others sections recorded data for machine downtimes due to mechanical maintenance problems, electrical maintenance problems, operational problems such as Lack of air, shortage of water, shortage of steam and lack of CO_2 for three consecutive years (from 2014 to 2016) which is given in the Figure 4.7, 4.8, 4.9.

The result for utility section about mechanical downtime, electrical downtime and operational down time for:

i. Annual year 2014 is 13.4 %, 22.4 % and 64 %, respectively.
ii. Annual year 2015 is 7.8 %, 7.5 % and 84.3 %, respectively.
iii. Annual year 2016 is 7.5 %, 13.2 % and 85.7 %, respectively.

So according to the above results the problems are due to operational problem accounts higher percentage of machine downtimes. From this it can be concluded that machine downtimes due to operational problems in this section reduces the production capacity of the industry.

4.1.3. Packaging Machine Downtime Status

The packaging section is one of the many sections found in the Factory and it is the main and the biggest section in the production process. As the name implies in this section the action of many operating machine is applied on the bottles, means from the entry of empty bottle at the inlet up to the outlets of beer filled bottle as a final product. But according to the above analysis in this section there is the down time it is caused by maintenance rather than other sections the year from 2014-2016. So in this paper the bottleneck machine in the packaging section and its root causes is determined based on the below tables:

Table 4.9. Packaging section three years average machine down time status (2014-2016)

	2014		2015		2016		Average	
Cause of downtime	Average mechanical downtime %	Average Electrical down time %	Average mechanical down time %	Average Electrical down time %	Average mechanical downtime %	Average Electrical down time %	Average mechanical downtime %	Average Electrical down time %
Machine	31.2	9.9	16.1	6.1	19.4	4	22.2	6.7
Labeler	18.5	9.8	16.4	3.2	8	6.7	14.3	6.6
EBI	0.5	7.7	0.9	12.9	3.2	13.1	1.5	11.2
Pasteurizer	6.8	7.4	6.1	5.8	8.8	5.7	7.2	6.3
Caser	9.3	5.4	7	2.9	2.9	8.3	6.4	5.5
Uncaser	4.1	7.2	6	2.8	5.3	3.4	5.1	4.5
Bottle Wasl	15.6	6.6	18	2.8	15.7	2.4	16.4	3.9
Crate Wash	1	0	1.1	0.2	1.8	0.4	1.3	0.2
Empty Bott	0	0.7	0	0	0	0	0.0	0.2
Full Bottle (	0.2	0	0.2	0	0.3	1.6	0.2	0.5

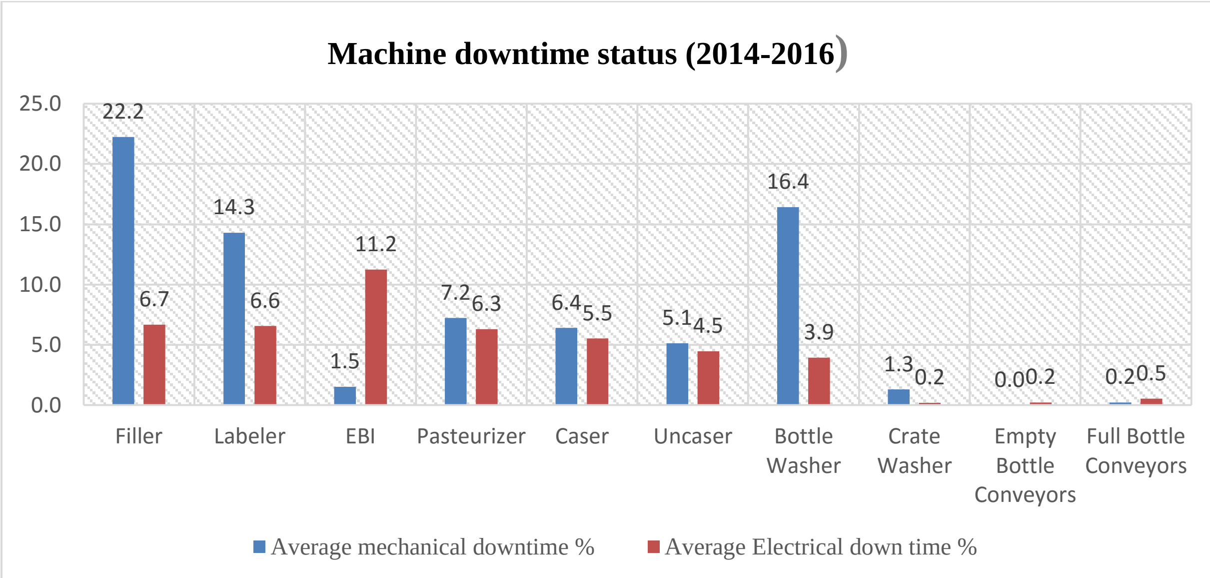

Figure 4.10 Packaging section three years machine down time 2014-2016

The bar chart illustrates machine down time status for consecutive three years starting from 2014-2016.

It can be seen that the status for machine down time in consecutive three years shows similar result through the year. Basically the status presents average mechanical and electrical machine down time of packaging section through three years. If we see status one by one, we can have clear image by seeing their average down time. Of the results that we have seen, filler machine has higher mechanical down time (22 %) than others. In terms mechanical and electrical down time, all the status in this section results in high mechanical down time. Thus, of the number of machines in the section most of them loss their production time due to mechanical down time.

In regards to electrical down time, comparing with mechanical downtime has less down time than mechanical. However, mechanical down time keep increased per machine and electrical downtime decreased since electrical downtime goes up and down from machine to machine.

Over all, the chart show that a clear upward trend in high mechanical downtime when goes through each year machine to machine, while electrical downtime seems less.

Features of the beer production process

In an increasingly competitive market place amongst the beverage industries, bottle filling industries in particular, show a clear and distinct need to improve their operations (Hanssen, 2002) .

The packaging process of the product has faced many challenges which could be alleviated through focused process improvement. Pareto analysis can be used as tool to identify key areas in the process and select the critical component that could benefit from a focus improvement initiative, thereby benefiting the overall company.

A generic beer production process involves eight manufacturing stages: (i) Malting, (ii) Malt Milling, (iii) Mashing, (iv) Cooking, (v) Cooling and Clarification, (vi) Fermentation, (vii) Maturation, and (viii) Packaging. The amount and type of raw material to be processed in each stage depends of beer type to be produced.

Packaging Line

This work is focused on the packaging step. In a packaging line, the beer drawn from a holding tank is filled into bottles, which are then capped and labeled. A flowchart of a common beer packaging process is depicted in Figure 4.11.

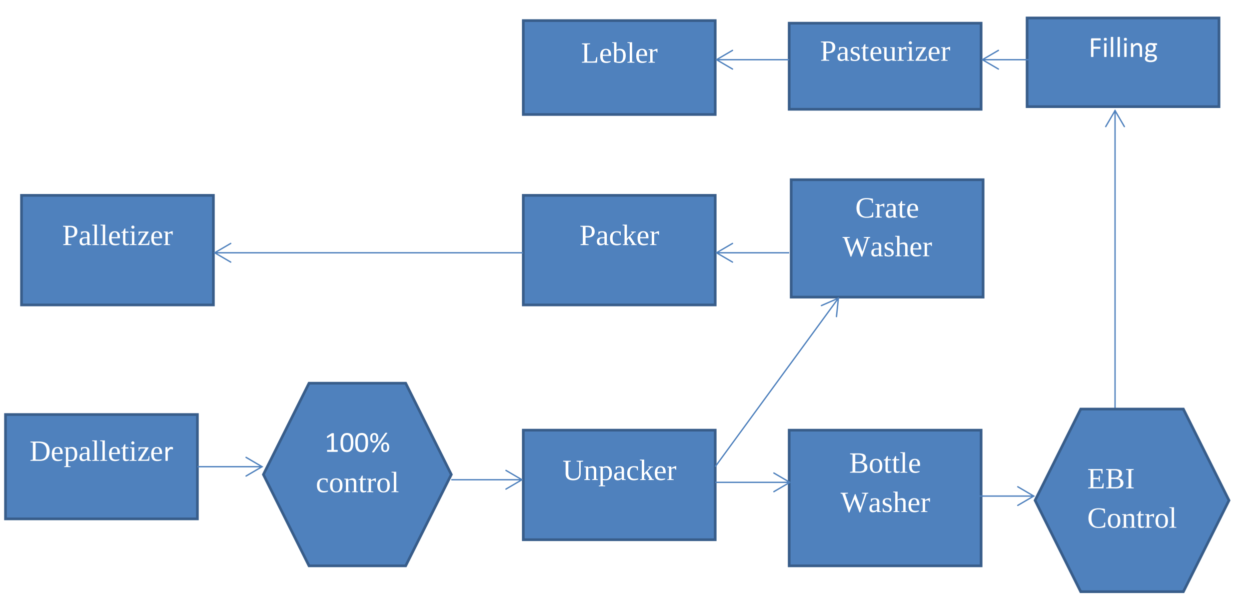

Figure 4.11: Beer bottling process

The first operation in a packaging line is the depalletizing stage, where the empty bottles are removed from the original pallet packaging. Then, an inspection operation named 100% control is performed manually by an operator so that defective items or bottles that could harm machines on the line are removed. After that, bottles and drawers are separated and then sent to washer machines in different lines.

The bottles must be rinsed with filtered water or air before being refilled. This physical and biological cleaning is performed to remove dirt, labels, adhesive, and foil from the glass bottles. The bottle enters then to a container inspector which controls that all cleaning agents used in a previous stage have been removed. Next, a filling machine is used so that the beer drawn from a holding tank is filled into the clean bottles. After that, a cap is applied to each bottle to seal it. To ensure the quality of product, the filled and capped bottles are then sent to a pasteurization stage, where they are kept until “minimum durability date”. Once the bottles reach this date, they enter to a labeling machine where a label is applied to each one. Then, a level-cap inspection is performed to reject bottles that do not satisfy required characteristics as filling level, internal pressure, and missing labels and caps. Finally, the product is located into drawers, which are packed into pallets and warehoused, ready for sale.

But this process is interrupted frequently due to the failure of components found on each machine; in order to identify the key components which causes higher down time, Pareto chart can be display categories of problems graphically so they can be properly prioritized. It indicates which problem to tackle first by showing the proportion of the total problem that each of the smaller problems comprise. This is based on the Pareto principle: 20% of the sources cause 80% of the problem.

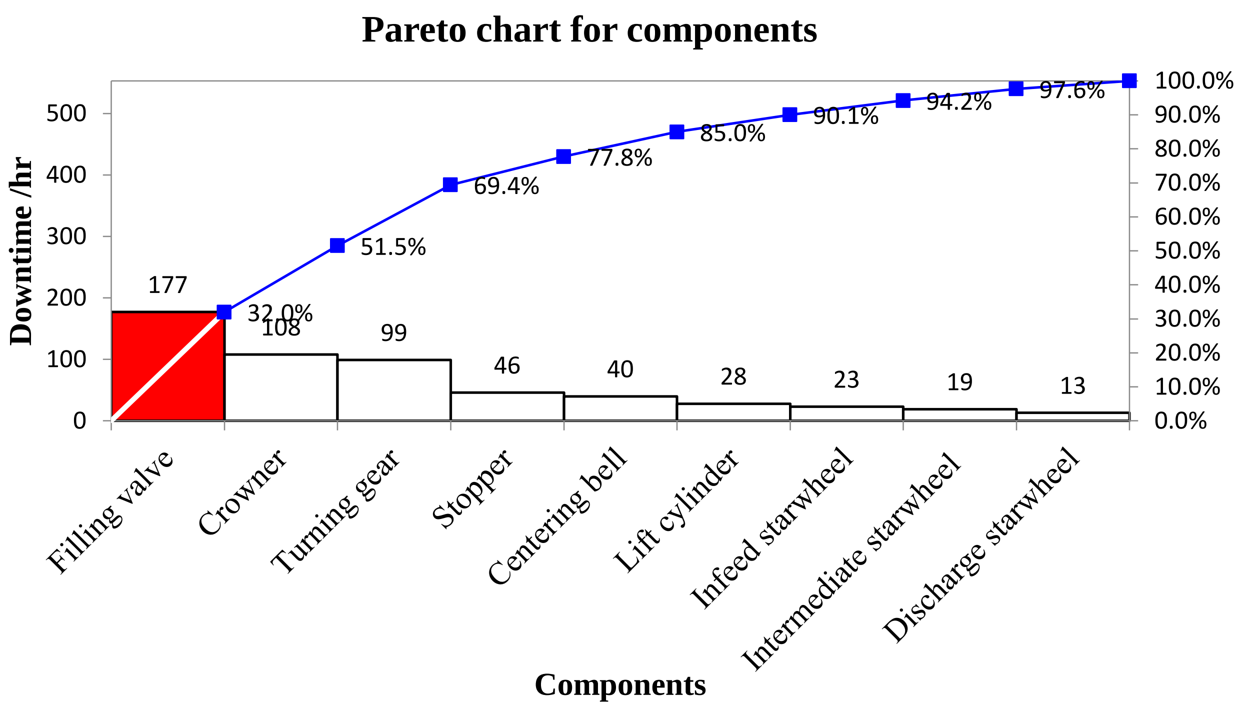

Figure 4.12 Pareto chart for components

It can be observed from the pareto chart in figure 4.12 filling valve comprising approximately 32% and it is the main reason for frequent failure of filler machine. Hence to improve the capacity of filler machine down time problems the first step that should be taken is give prioritize to the filling valve by using RCM.

4.1.4. OEE Calculation

The OEE as mentioned in the literature consists of three components, where the first is the machine availability (A). This component of the OEE measure is concerned with the total stoppage time resulting from unscheduled down time, process setup and change over and other unplanned stoppages. The second component of the OEE calculation is the performance efficiency (PE) and the actual amount of production is measured. This component is affected by the speed of the production line and from minor stoppages. The third component of the OEE calculation is the quality rate (QR), which is the proportion of good production to the total production volume. The QR is related immediately to the defective production of the line.

In order to start the OEE measurement process, operational performance data collection of the three OEE variables has been collected during a period of 12 months.

A= (Loading time – Downtime)/Loading time

PE= (Processed amount * Actual cycle time)/Operating time

QR= (Processed amount - Defect amount)/ Processed amount

OEE= Availability* Productivity efficiency* Quality rate= A * PE * QR

Table 4.10.Actual OEE values calculated for each month and for the entire period of operation

Month	**Process Amount ,in hrs**	**Defect Amount ,in hrs**	**Operation Time, in hrs**	**Actual Time, in hrs**	**Loading Time, in hrs**	**Downtime , in hrs**	**Q (%)**	**PE (%)**	**A (%)**	**OEE (%)**
1	593,521	6217	712,725	847.84	1,170	311.11	0.99	0.83	0.72	59.72
2	650,959	3751	712,725	929.94	1,170	240.06	0.99	0.91	0.79	72.19
3	593,913	10953	712,725	848.45	1,170	321.55	0.98	0.83	0.73	59.31
4	633,247	5287	712,725	904.04	1,170	265.36	0.99	0.89	0.77	68.12
5	615,797	6797	712,725	879.71	1,170	290.29	0.99	0.86	0.75	64.25
6	565,279	5791	712,725	807.54	1,170	362.46	0.99	0.79	0.69	54.18
7	567,508	4396	712,725	810.73	1,170	359.27	0.99	0.8	0.69	54.75
8	457,376	5216	712,725	653.39	1,170	516.61	0.99	0.64	0.71	45.04
9	477,993	3593	712,725	627.70	1,170	544.3	0.99	0.61	0.69	42.65
10	558,808	7480	712,725	790.30	1,170	371.7	0.99	0.78	0.68	52.78
11	494,698	3850	712,725	706.71	1,170	463.29	0.99	0.72	0.75	53.58
12	530,137	6529	712,725	759.34	1,170	412.66	0.99	0.74	0.76	55.83
Ave.							0.99	0.79	0.73	56.82

The actual availability, performance efficiency and quality rate measures together with the complete OEE for each month are shown in the above table and the actual OEE values calculated with the three components (A, PE & QR) for each month and for the entire period of operation, therefore the following observation can be made:

The actual QR (0.99) exactly meet the target (99%) (Levitt, 1996), the availability of the line is 73% which withhold enough from the target (90) and the actual PE is & 79 % also withhold enough from the target 95%. The OEE performance of the line is low 56.82 % considering the target of 85% (Hanssen, 2002), the main causes are speed losses and high down time.

4.2. Total cost of production in DBSC

Profitability increase, as the most important business objectives, can be achieved through various savings. Many studies indicated that savings in maintenance always have the largest and direct value in all savings (Al- Najjar & Alsyouf, 2004). To monitor and to control maintenance cost, elements of maintenance cost have to be defined and linked to the corresponding maintenance operation.

To produce beer in bottle there are costs for the industry are direct cost, indirect cost, overhead cost. The amount of total cost of each type for 2016 is taken the annual report of the company as follow:

Table 4.11 Total costs of the company for 2016

Types of costs	Cost in birr
Production cost	572,612,819.21
Operation cost	153,657,251.1
Maintenance cost	13,287,975.21
Total cost	739,558,045.5

With this total production cost, the company makes the net profit 473,346,460.8 birr in the year.

4.2.1. Maintenance cost of packaging section

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

Table 4.12 Maintenance cost of the company in 2016

Maintenance Costs	Maintenance Cost in birr	Maintenance Cost in %
Employee wage	6,860,426.07	51.62
Spare parts	4,969,940.14	37.4
Over time	851,694	6.4
Other	605,915	4.55
Total cost	13,287,975.21	

The current equipment and machinery maintenance activity of the company consists of both preventive and corrective. But as could see in the analysis part the corrective maintenance activity highly dominated the preventive activity so this leads the company to high down time and faced with high maintenance cost.

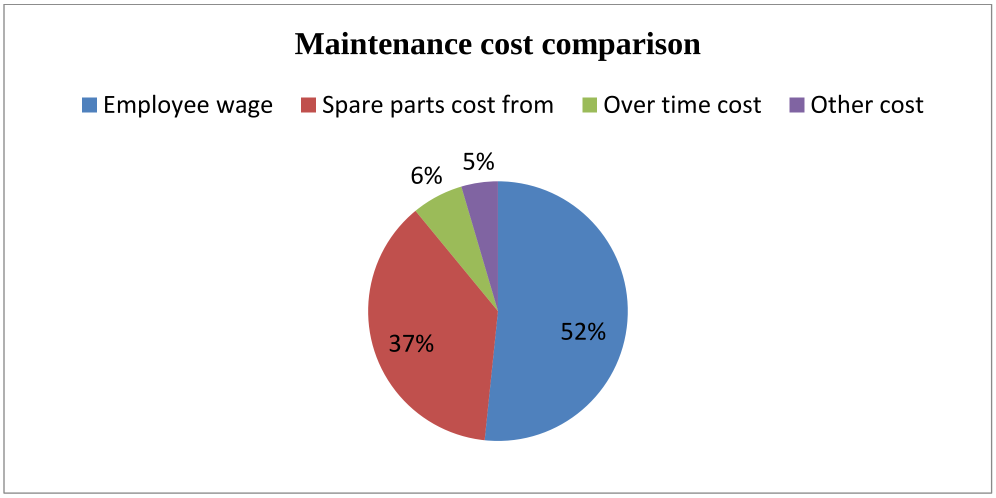

Figure.4.13 Maintenance cost comparison of the company in 2016

As it is shown in the diagram, the high maintenance cost is the wage of labor and spare part cost. But the objective of this paper is decrease the maintenance cost so if the proper maintenance system is applied and operations are aware about their own machine, the costs incorporated with spare parts decrease dramatically.

Over time cost is always should be avoided, thus the number of break down jobs decrease the amounts of the overtime will decrease. How to decrease these breakdowns is the main objective of the study and will be discussed in the next chapter.

4.2.2. Downtime cost analysis

In DBSC the machines are arranged series arrangement, the breakdown of one machine affects the whole production process especially for bottleneck machine. Under this title the status of bottleneck machine is analyzed to know how much it costs if failed.

Packaging section maintenance cost analysis

The capacity of filler machine in average is 31,000 bottles/hr, thus in the packaging house the capacity of machines with the associated cost/hr is calculated in the Table 4.13. The failure of machine results to decrease the output that the machine can produce, therefore the cost lost in each hour due to the breakdown is calculated using the net profit on the final product.

In the budget year 2016 the company produce 242,741,000 bottles, the total cost of production is 115,562,647 birr and administration cost is 123,344,951, the revenue in the year is birr 777,369,135 and the tax that the company paid is 188,461,538 thus the average net profit of one bottle can be calculated as:

$$\text{The average net profit per bottle} = \frac{Revenue - total\ cost - taxs}{Bottles\ sold}$$

$$= \frac{777{,}369{,}135 - 238{,}907{,}598 - 188{,}461{,}538}{184{,}210{,}525}$$

$$= 1.90 \text{ birr/bottle}$$

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

Amount lost birr per hour = actual capacity *net per each bottle piece

Table 4.13 Summary of actual capacity and downtime loss

Type of machine	Actual capacity (bottle/hr)	Downtime loss (Birr/hr)
Filler	31,000	58,900

After calculating the down time cost per hr for each machine, the total amount of money that the company lost due to unavailable of processing machine. Thus the bottleneck machine for beer processing machine are selected and shown in Figure 4.10. The down time cost for bottleneck machine (filler machine) and its down time per year is on average 1144 hr/year, then the total loss of the company due to the unavailability of processing machine. The Table 4.26 displays the total loss for beer processing machines.

Table 4.14 The actual hourly capacity and the downtime loss

Mechanical Down Times By Machine	**Down time (hr/yr)**	**Down time cost (birr/hr)**	**Total downtime cost (Birr/yr)**
Filler	1144	58,900	67,381,600

The total down time loss due to breakdown of packaging section is 67,381,600 birr. And the net profit in the year is 349,999,999 birr. Thus the company's loss in the year 2016 due to breakdown is:

$$\frac{67,381,600}{349,999,999} * 100 = 19.3\ \%\ \text{of the profit}$$

In conclusion the ultimate profit that the company could earned through efficient maintenance management can be estimating by adding the net profit with in the year and the cost associated with down time. Here the amount of spare part cost is not included since the portion of the cost that caused due to improper breakdown is not clear known. So the amount of money lost in the year 2016 due to machine breakdown cost is: 67,381,600 + 13,287,975.21= 80,669,575.21 birr

$$\frac{80,669,575.21}{349,999,999} * 100 = 23.04\ \%$$

Therefore 23.04 % of the additional profit could have been found if the company implement RCM and use the frame work.

4.3. Finding and Discussion

The evidence presented from the survey and secondary data the level of implementation of proper maintenance system is very low. This could have a direct effect on the firms' productivity. Thus production becomes very costly and less reliable.

Machine downtime is one of the main issues for maintenance performance unlike operational activities. According to the above data from the 2014-2016, there is down time in the packaging section which is caused by maintenance problems than other sections. Therefore, the filler machine is the bottleneck which has high down time and the critical component of the machine is filling valve. So, it can be concluded that improved maintenance system in packaging section has a bigger role to decrease downtime to increase production capacity of the company.

From the survey questionnaire result as shown in as the problems for high machine downtime and reduced machine capacity is mainly due to not giving priority to critical components and lack of training concerning maintenance activities are provided to the maintenance operators at the company. Training should be mandatory for maintenance personnel as it is one of the ways to increase productivity. Training, that the operators require, is interpersonal skills, the ability to function within teams, problem solving, decision-making, job management performance analysis and improvement, and technical skills, and this problem is due to the centralized management, which cannot easily meet the condition that makes the running production system as efficient as possible (Levitt, 1996). So, this issue has a negative impact on DBSC, consequently, training programs are very important for improving their skills and enables them doing their job effectively.

The other root cause of machine downtime is due to lack of awareness by the management about maintenance activities and insufficient support of maintenance technician and production operators to work together on problems. The main implication for managers that has emerged from the study is that managers in manufacturing companies should place emphasis on assessing and monitoring the impact of maintenance on company’s business (Maletic, Maletic, Al-Nejjar, & Gomiscek, 2012). Therefore, managers could identify the potential benefits of maintenance policy in terms of productivity, quality and profitability.

Recent surveys have shown that approximately 70% (David, 2014) of food and drink industry still operates a breakdown maintenance system and that the available technologies are not being used as effectively as they should be. Organizations claiming to have a “planned” maintenance program rarely meet their targets, usually because of unexpected breakdowns. While some organizations have successfully implemented some of the available tools and technologies, they are not in common use, and methods need to be devised to assist with the process of implementation. One of the major problem in DBSC is the management of spare parts is executed insufficiently, critical spare parts that are required on a frequent basis are not available in the store and poor or incomplete plans and the company employees are not fully aware of the concept and benefits of preventive maintenance and this problems at all parts of technical department. Designing and implementing a correct maintenance strategy is essential for a company’s competitiveness. So increase the availability of the machines can be achieved by focusing on preventive maintenance.

A considerable amount of literature has been published in relation to the definition of OEE and its various applications. (Muthiah et al. , 2008) (Hanssen, 2002) reported that the overall equipment effectiveness (OEE) metric is a powerful tool that can be used to measure performance and also perform diagnostics at the equipment level and the OEE should be higher to 90%, whereas for continuous on stream processes industries should have OEE values of 95%

or better. But in this company the OEE result is low which 56.82 %, therefore this indicates that there should be an improvement in the current maintenance system. The operation of the Dashen production line is not as expected, therefore the components PE and A should be improved immediately, because according to (Khan & Darrab, 2010) a good maintenance policy and strategy leads towards improving equipment reliability and maintainability, maximizing overall equipment effectiveness (OEE) and acts as contributor to quality and to higher productivity. In addition, to avoid the inconvenient impact of the failures on the production process, it is strongly recommended to upgrade the operation management prioritize for critical components, parts replacement decisions, training programs for technicians/operators, spare parts requirement etc.

In many study's (Al- Najjar & Alsyouf, 2004) (Muthiah et al., 2008) authors have emphasized the role of maintenance in improving performance and profitability of manufacturing processes. This suggests that maintenance is no longer a cost center, but could be profit-generating. In general, improvements in the performance of a maintenance policy aim to reduce production cost and increase company's profit and competitiveness through enhancing process availability, performance efficiency and quality rate.

While empirical finding provide interesting insight in maintenance in relation to company's capacity, this can be also discussed in the view of the current state of the maintenance activities in the company.

So this study seeks to investigate the barriers down times problems which hinder the success of the maintenance system applied in DBSC and explore RCM as a strategy to help to ensure the operating continuity of production system at high efficiency and thus continued productivity.

CHAPTER FIVE

RCM MODEL IMPLEMENTATION

The result from data analysis shows that the causes of machine downtimes for each section, i.e. packaging, brew house and utility. The result indicates that machine downtime in packaging section is identified as the major one based on the results of prioritizing the critical components, lack of training on maintenance activities, lack of awareness by the management, insufficient spare parts, poor or incomplete maintenance plans. Since this section covers the largest portion of the production, where most of the activities are accomplished, as a result, frequent machine breakdowns have occurred because of the above listed problems. This shows maintenance practice for each machine is poor and result in less productivity. Thus, the main intention of this chapter is to focus on improvement of productivity through reliability centered maintenance that was focus on the root cause of maintenance problems.

5.1. Reliability Centered Maintenance (RCM)

The need to improve the reliability of production system and promote uptime and availability has become one of the most important factors in the improvement of maintenance. RCM is a technique to develop preventive maintenance and could make very significant savings in maintenance cost and ensure the availability of production system. According (Moubray, 1997), if RCM is correctly applied, it can reduce the amount of routine maintenance work by 40–70%. The benefits of RCM can usually be traced back to two broad categories: risk reductions and cost savings (Johnston, 2002) and to minimize equipment life-cycle costs (LCC) and maximize overall equipment effectiveness (OEE) by maintaining/ increasing the probability that an asset or system will function satisfactorily if it is used according to the set desired specifications. It is accomplished by identifying the failure modes and effects of each part or component (Geert & Liliane, 2002) .

This research attemted to understand the current implementation strategy in DBSC and to explore how to adopt an effective maintenance stratery like RCM. It is used to minimize the problems that mentioned the above, decrease maintenance cost and enhance the productivity of the company.

Due to these reasons, the study needs to find ways through improved maintenance that ensures the reliability of production systems. Then, the factors that are affecting the success of maintenance were addressed through implementation of RCM strategy. This was done along with studying the circumstances that should be addressed to ensure the success of implementing RCM.

RCM uses a Logic Tree to Screen Maintenance tasks; this provides a consistent approach to the maintenance of all kinds of equipment.

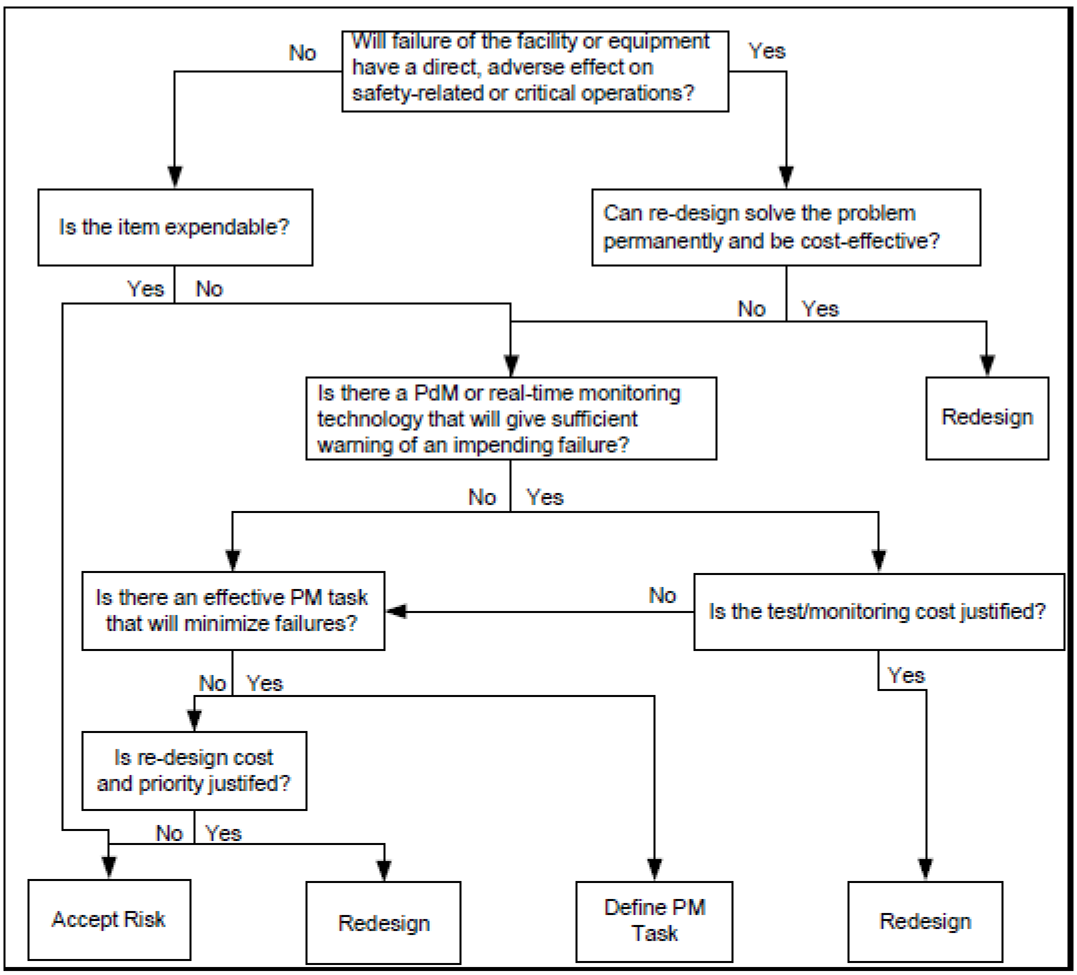

Figure 5.1: RCM Logic Tree (Devaraj Naik & Pradeep , 2016)

5.2. Elements of RCM frameworks

This section represents the elements and their sequence in different existing RCM frameworks in literatures. RCM and a structured implementation process can be one of the success factors for the RCM program in an organization. The structured implementation process is usually represented in the form of a particular framework and a framework can act as a guide and it provides a structured way to achieve its objectives. And there are different frameworks at RCM have been studied, (Fonseca & Knapp, 2000) developed a new framework for RCM implementation in the chemical process industry, (Penrose, 2005) applied RCM techniques on electric motors, (Dehghanian & Aminifar, 2013) proposed a method to adopt the principles of RCM in power distribution system in the form of a practical RCM framework, (Gang & Michael, 2009) presented CBM framework with RCM, (Chen & Zhang, 2012) described the implementation of RCM in China's nuclear energy field, (Deepak & Jagathy, 2013) developed a new RCM framework in Indian refineries oil industry. Among these frameworks only few frameworks can use for processing industries, like Brewery industries.

RCM Framework

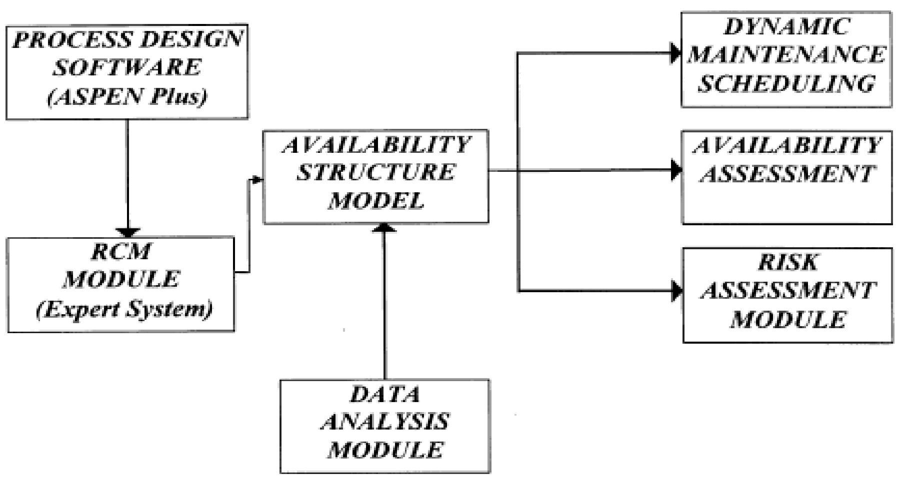

Figure 5.2. A proposed industrial equipment reliability management environment (Fonseca & Knapp, 2000)

This research was oriented to the development of a new computerized RCM framework to be employed as the basis of the preliminary design for production processes on chemical industry. But in paper Fonseca used Fuzzy reasoning algorithms to evaluate and assess the likelihood of equipment failure mode precipitation and aggravation. Because RCM is measured by FMEA, it is used to prioritize the critical equipment and identify the failure mode and effect. And also this frame work does not include performance measurement of actions.

RCM Model

The maintenance response to the need for preventing failures has been to have a Predictive Maintenance program that has both condition-based tasks and time-driven tasks. Condition-based tasks are derived mainly from Vibration analysis. Time-driven tasks typically arise out of equipment manufacturer recommendations and are conventionally referred to as PM Tasks or PM Plans. In addition to the PM Plans and the PdM plans, most organizations employ a Root Cause Failure Analysis program (RCFA). In the case of Indian refineries the Oil Industry Safety Directorate (OISD) has through its standards specified the type of maintenance strategies to be adopted by these refineries. Considering these facts the present model of maintenance and reliability assurance practiced in general in Indian refineries is displayed in the figure.

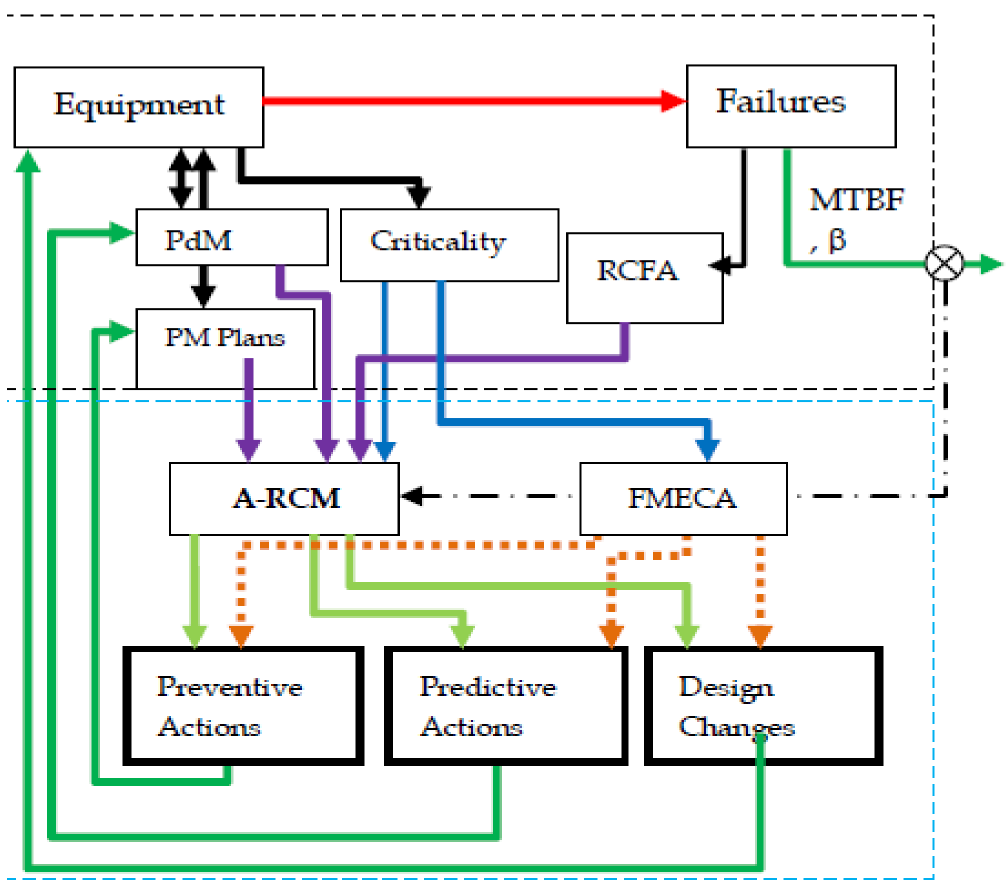

Figure 5.3. RCM Model (Deepak & Jagathy, 2013)

Since Brewery Company is a process industry, it is possible to use Prabhakae and Raj model developed for petroleum industry, but the model has determined the criticality of the component before analysis, the criticality of the component should be determine by using Failure mode and effect analysis (FMEA), the existing model does not include the performance measurement of preventive and predictive action, this is used to continuous improvement.

Reliable and Risk Centered Maintenance Framework

This study is one of the first to investigate the reliability of preventive maintenance planning by consideration of Reliable Centered Maintenance (RCM) and Reliability and Risk Centered Maintenance (RRCM) in offshore wind farm projects.

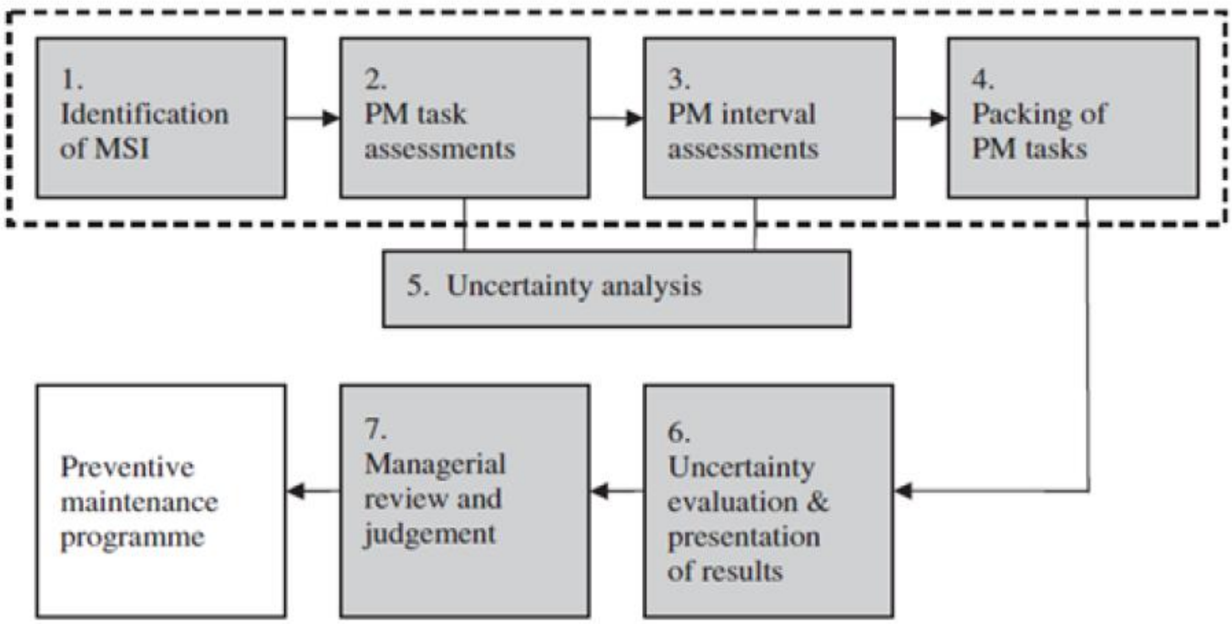

Figure 5.4. Reliable and Risk Centered Maintenance Framework (Manouchehrabadi, 2011)

The above framework include both reliability centered maintenance (RCM) and risk reliability centered maintenance (RRCM) focused on uncertainty evaluation and reliability, this framework deals only on preventive maintenance strategy that doesn't include the other maintenance system ,such as predictive maintenance, corrective maintenance and others, because, it is not possible to protect all the failures using preventive maintenance.

FMEA approach for RCM improvement

This framework is developed to provide a cost effective and satisfactory maintenance schedule for improvement of the RCM procedure based on the failure mode and effect analysis (FMEA) is developed on Oil and Petroleum industry.

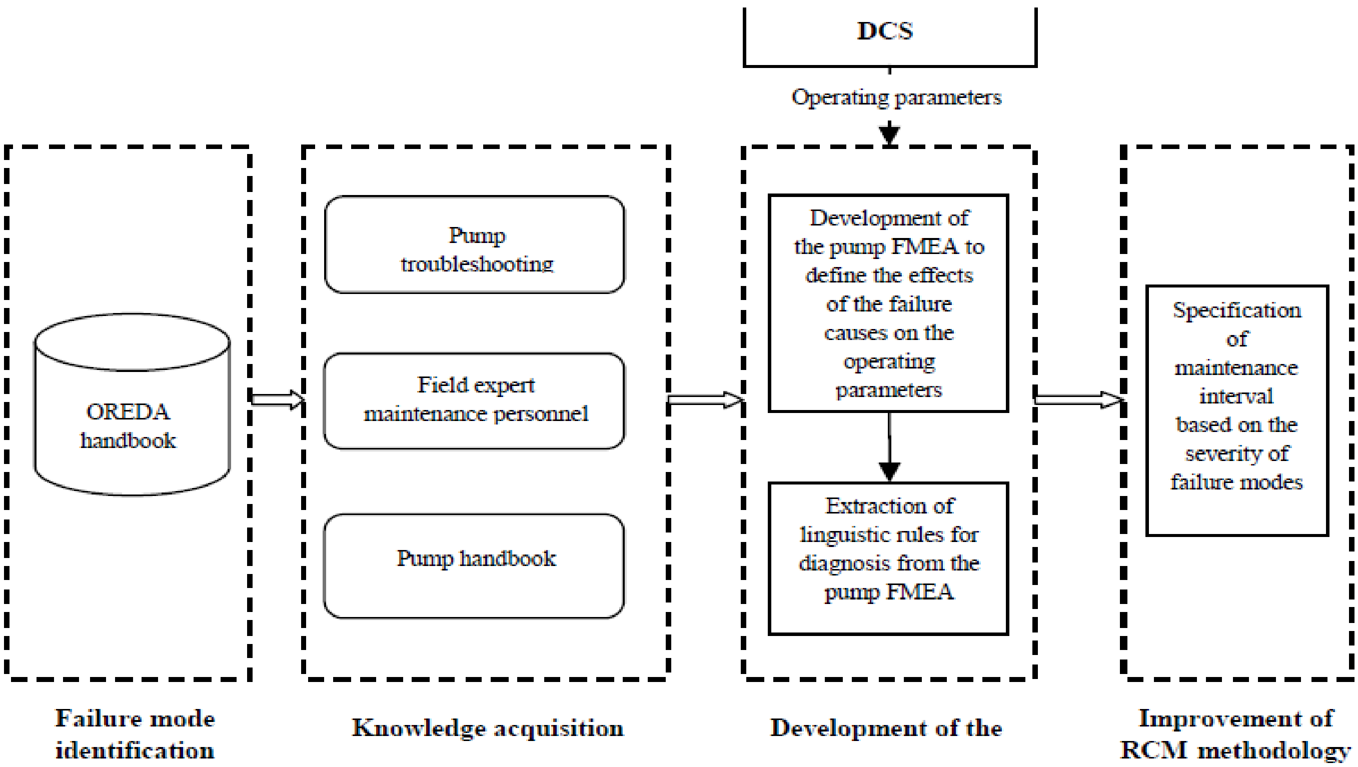

Figure 5.5.The schematic structure of the proposed FMEA approach for RCM improvement (Ebrahimipour, Bavar, & Azadeh, 2009)

The above framework developed for RCM and FMEA based on the knowledge acquisition from manufacturer pump trouble shooting, field expert maintenance personal and pump hand book for specific centrifugal pumps, it is one way forward loop, it has no feedback system.

5.3. Proposed RCM model

RCM is an important tool for continuous reliability improvement. Since Brewery Company is a process industry, it is possible to use Prabhakae and Raj model developed for petroleum industry, by adjusting and making major changes. However, there is a need management commitment for implementation of the model, to decrease the root causes of improper maintenance and to improve the productivity of the company. RCM helps to achieve a sufficient preventive maintenance plan, which is reduces the cost of maintenance and at the same time it enhance reliability and safety: reliability is the focused of Reliability Centered Maintenance. Objectives of this model are to provides immediate improvement in reliability and minimize the cost to increase the productivity of the company. The model prioritize the aggregates and components of the system using Failure mode and effect critical analysis (FMECA) and Root cause failure analysis (RCFA). Then the correct decision will be made after analysis.

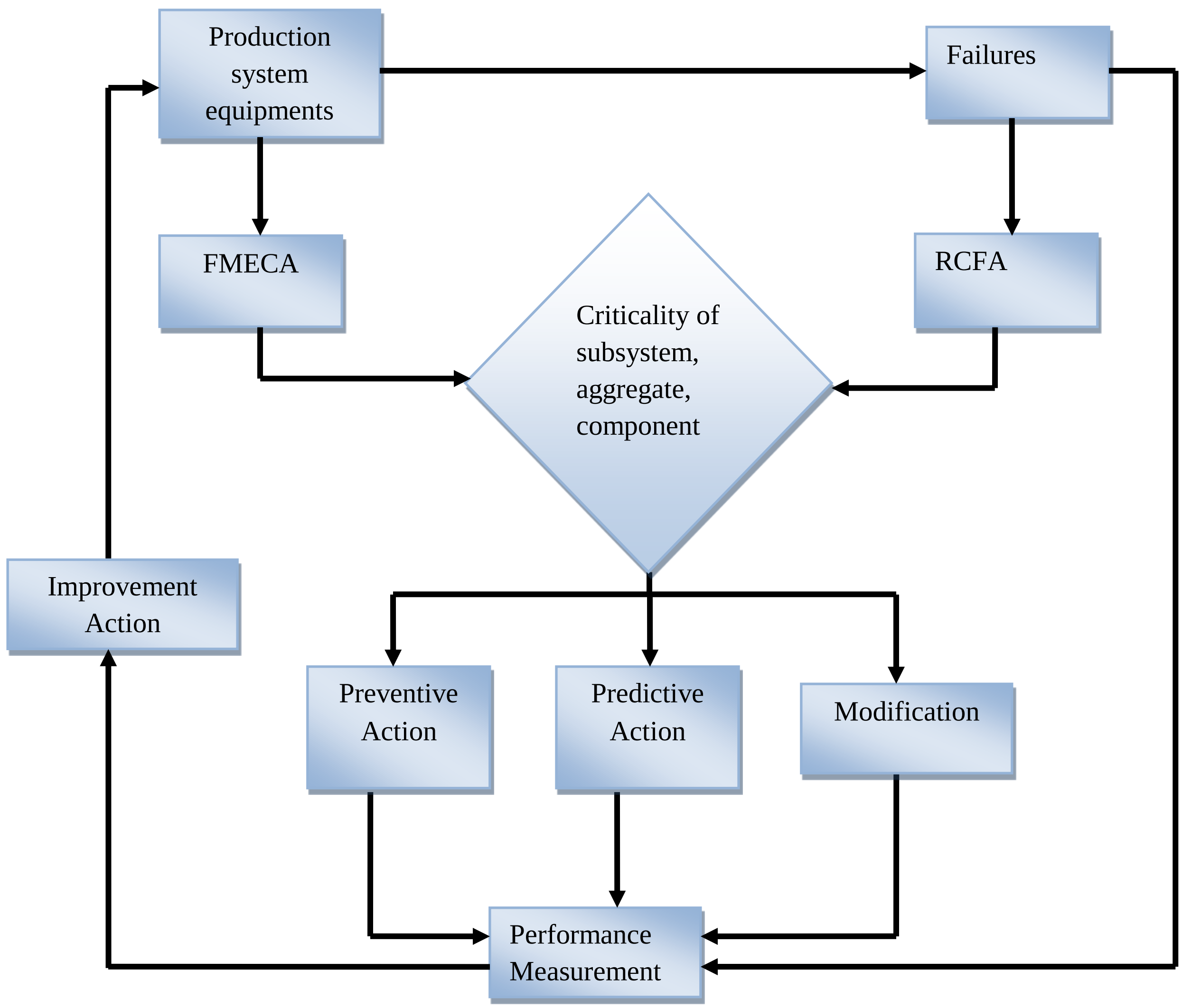

Fig.5.6 Proposed RCM model for DBSC

Identification of Critical Components

As it is mentioned before, the first step of the RCM process is identification of critical components. The following question could lead us to a good point to identify the critical components **(Nilsson, 2009)**.

1. What are the functions and performances required?
2. In what ways can each function fail?
3. What causes each functional failure?
4. What are the effects of each failure?
5. What are the consequences of each failure?
6. How can each failure be prevented?
7. How does one proceed if no preventive activity is possible?

5.3.1. Determination of Preventive Maintenance

Based on the Failure Mode, Effect and Critically Analysis FMECA results, Preventive Maintenance (PM) tasks are determined by application of Reliable Centered Maintenance RCM logic. It consists of communication between management and the project group about how the maintenance should be practiced. Quality assurance also helps in this phase to identify some issues which were overlooked or ignored in Failure Mode, Effect and Critically Analysis FMECA phase.

5.3.2. Maintenance performance indicator

Maintenance and plant managers need performance information to monitor and control maintenance processes and results and provide indication towards improvement. Performance measures support the building of actions necessary to attain equipments performance as required by the strategic goals. It is in the interest of managers to measures the efficiency and effectiveness of maintenance process, establishes the relationship between maintenance inputs and outputs, and therefore justifies investments in maintenance. The maintenance measurement indicators such as, OEE, MTBF, MTTR have been widely recognized as vital for the management of maintenance operations. Therefore DBSC will have the information and known about the performance of equipments when used the maintenance measurement indicators.

5.3.3. Failure Mode, Effects and Criticality Analysis (FMECA) for Filler Machine

Failure Mode, Effect and Critical Analysis (FMECA) can be used in reliability analysis to identify critical components. It could help to determine the connection between possible failure and the failure effects. The main purpose of that is to find all ways that the component can fail. It helps to identify critical components. To gather enough data some questions should be answered like what failure could appear? What are the effects of the failures? What are the causes of the failures? Next step after finding the answers to the mentioned question is time of clarification of frequency of each failure which should be done base on experience (Nilsson, 2009).

This RCM seven Question process helps to determine the causes of system failures and develop activities targeted to prevent and priories them. The questions are designed to focus on maintaining the required functions of the system and help to conclude best maintenance strategy.
In table 5.1 the answers of questions are recorded which are related to functional failure, causes and effects, are recorded in RCM information sheet. Decision worksheet is recorded with the help of answering question in RCM decision diagram related to preventive tasks and default actions.
Filling machine may include: filling valve, centering bell, infeed starweel, Lift cylinder, Intermediate starweel, Stopper Discharge starweel, crowners, and Turner gear.
Filling equipment and operation and monitoring functions may be directly controlled or involve the use of a process control system.

Table 5.1 Filler Failure Mode Effect Analysis

Item	Identification	Function	Functional failure	Failure mode	Effect	Preventive tasks	Default actions
1	Stopper	To avoid damage occurring at the bottle infeed	Unable to stop the bottle	Wear and tear	Bottle Broken	Conveyor and worm gear adjustment,	Change
2	Infeed starwheel	Picks up the bottle from the infeed worm and transfer it to below the filling valve	Unable to picks up the bottle	Wear	Bottle Broken	Conveyor and worm gear adjustment,	Change
3	Centering bell	Centers the bottle below the filling valve	Unable to centering	Bendiness	Bottle not straightness	Inspection	Service (replace)
4	Filling valve	The product valve opens automatically as soon as the bottle has been slightly filled	Unable to meet standards	O-ring rubber wear, looseness	Over/Under fill	Cleaning (weekly)	Replace with new
5	Lift cylinder	Raises the bottle and press in onto the filling valve	Unable to press the bottle	Broken	Not straightness	Lubrication, Inspection	Service
6	Intermediate starwheel	Picks up the bottle and centers it below the sealing head	Unable to picks up the bottle	Wear	Bottle Broken	Conveyor and worm gear adjustment,	Change
7	Crowner	The neck guide holds the bottle at the correct position underneath the sealing head closes the bottle	Unable to close the bottle	Nut Looseness, crowning pistons	Missing crowns, rework cost	Lubrication	change
8	Discharge starwheel	Discharge the conveyor after the bottle has been closed	Unable to discharge the conveyor	Wear	Bottle Broken	Conveyor and worm gear adjustment,	Change
9	Turner gear	Drives the main gear and acts as a machine brake	Unable to rotate at 1500 rpm	Motor failure	Machine stoppage	Lubrication (oil/grease)	Service (replace)

Once the maintenance objectives and strategy are defined, there are a large number of quantitative and qualitative techniques which attempt to provide a systematic basis for deciding what assets should have priority within a maintenance system, a decision that should be taken in accordance with the existing maintenance strategy.

Therefore, the FMECA on table 5.1 in the process of filler machine a device which performs an important role is identified as a critical component, which is filling valve. Losses are defined as loss of product from the stated liquid tank agreed volume and the volume of product exiting the filler less all rejects. The only way to control liquid product loss is to identify the main problem areas in order to effectively work towards minimizing the losses. Liquid tank to filler loss is product lost prior to the filler valve monitor on the actual filler machine. These losses include incorrect declared and agreed volumes of the liquid tank. So FMEA prioritize the critical component i.e, filler valve by recognizing based on the failure mode, effect and critically analysis (FMECA) results of the component to reduce down time of the filler machine.

So FMECA prioritize the critical component by recognizing based on the failure mode, effect and critically analysis (FMECA) results of the component to reduce down time of the filler machine.

In the filler machine unscheduled breakdown of critical components like filling valve can cause production and other consequential losses. One of the identified critical components is filling valve, in which may cause other defects like wear, over or under filling etc. The problem of under filling reduces the total production capacity, i.e 744,000 bottles /day, of the filling machine and the planned loss due to under filling of the product per day is 0.2% of the total production, i.e 1,488 bottles, but now the loss due to under filling is 1.5% of the total production, i.e 11, 160 bottles. Therefore, RCM can solve this under filling problem by understanding the filling valve function, failure mode, effect analysis and enables to get maximum efficiency of the filling valve and improve the productivity of the filler machine.

RCM can be defined as a mix of more than one maintenance strategies in an optimized manner in order to reduce the system risk. For a successful RCM plan, the degree of risk of each fault should be identified in order to define the optimum maintenance actions (Ebrahimipour, Bavar, & Azadeh, 2009). The main items in the implementation of RCM according to FMEA are the prioritization of the failure modes according to their consequences on the system and modeling the probability of failure.

The implementation of RCM was thus considered for DBSC to minimize profits losses while improving plant availability performance. In implementing RCM is optimally integrated to increase the probability that the equipment will function as required over its design life-cycle with a minimum amount of downtime and maintenance. By so doing, the respective strengths of all strategies are utilized to maximize the reliability and availability of equipment though minimizing life-cycle costs. The RCM process produces effective maintenance decision to be supported by sound technical and economic justification.

The model can be applied for all brewery companies 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 brewery companies is the capacity, which comes from the number of machines each company has.

In DBSC the productivity and profitability is decreased due to mechanical down times with different root causes as mentioned before, since the designed production capacity of the industry is 48,000 bottles /hr and its actual production capacity is 31000 bottles/ hr and the industry produce 64.5 % of its designed production capacity. But if the industry implements the proposed solution which alleviates the problems whose contributes to the down times of the machines and the industry can almost meet its planned production capacity, i.e. 42,000 bottles/ hr, which means the industry produces 87.5% of its designed production capacity.

In terms of money from cost analysis the industry loses 13,287,975.21birr annually due to maintenance cost and 67,381,600 birr annually due to machine down times and this cost accounts 23.04 % of the total profit of the industry, i.e. 349,999,999. And the company can reduce this loss of money due to maintenance and downtime costs and increases its profit by 23.04 % and improve productivity by implementing RCM.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1. Conclusion

In this thesis, a detailed investigation of causes of maintenance problems of Dashen Brewery Share Company has been conducted and enhancement of productivity through improved maintenance system is given.

Machine down time is one of the main problems for maintenance in the company in the three sections and the down time in the packaging section is higher in percentage than the other sections. The result obtained from the analysis part shows that the filler machine is the bottleneck for production which has high down time that the other machines and filling valve is the critical component. From the survey questionnaire result the problems for high machine down time and reduced machine capacity is didn't give prioritized the critical components and analyzed using FMEA lack of training on new technology which is provided for the maintenance craft employees, since this has a negative impact on DBSC. Therefore, training programs are very important for improving their skills and enables them doing their job effectively. Lack of awareness by the management about maintenance activities, insufficient support of maintenance technician and production operators to work together on problems, inadequate spare parts, which is critical spare parts that are required on a frequent basis are not available in the store, poor or incomplete maintenance plans and the company employees are not fully aware of the concept and benefits of preventive maintenance at the company, so increase the availability of the machines can be achieved by focusing on preventive maintenance.

The OEE of the line is low i.e. 56.82 %. The result of the study shows that the main factors lie behind the lack of proper maintenance involves and how important it is.

Therefore, it can be concluded that improved maintenance system in packaging section has a bigger role to decrease down time to increase production capacity. Among the maintenance tools, RCM is a strategy by which production system can be taken to the higher level of reliability to ensure continuous productivity in DBSC. RCM as an approach is based on the identification of components whose failure can cause undesirable consequences and directly affect the continuity of production in the company.

To preserve equipment function, RCM seven question analyses performed in case study and predictive maintenance selected on basis of RCM analysis instead of preventive maintenance to identify causes of pending damage. So, it benefits in two ways by repairing equipment before failure and increase reliability by eliminating root causes. In this way, RCM helps to plan scheduled maintenance when required and scarce economic resources on critical equipment having high risk of failure. The paper reveals that the company can achieve enhanced productivity leading to competitive advantage with successful RCM implementation through selecting appropriate maintenance strategy.

Implementation of proposed model in the company can meet the planned capacity, i.e. 42,000 bottles/ hr, which is the company produces 87.5% of its designed capacity and the loss of money due to maintenance and downtime costs and the company increases the profit by 23.04 % and can improve the productivity. The results show the importance of the development of maintenance strategies through the implementation of RCM in this factory and depending on the problems the model is developed. The purpose of it would be to overcome the problems that could secure the reliability of the production systems.

6.2. Recommendations

The framework which is given as a proposed solution to improve maintenance problems that are discovered throughout the study should be implemented by Dashen Brewery Share Company, so as to reduce machine downtimes, improve productivity, avoid loss of money and increase profitability. The following recommendations are proposed for the company based on the outcome of the thesis.

a. The company should make use of an advanced computerized maintenance management system. So proper use of the CMMS provides the employees with more structure in their work, it provides organized data for maintenance and production, which are important for decision making.
b. The company should give an emphasis on providing regular trainings on maintenance to upgrade the technical and problem solving ability of technicians because when

machines faced with maintenance problems the technicians can maintain the equipments within a short period of time and bring back to work.

c. Technical workers should create an awareness and commitment for the top management and explain for them the money lost due to machine down times and maintenance problems.
d. Preventive maintenance activities should be practiced in the company, as it is the better solution to increase the availability of equipments; the production department staffs also should understand preventive maintenance activities and should provide the equipment whenever needed.
e. The company should give priority for critical spare parts at the time of purchasing and should avail the spare parts in the store to use whenever needed because delay in spare part is one of the main causes of down time.

That being said, having a maintenance organization should be considered in the plant to further outline the significance of maintenance and its role in the production profitability of the company. Thus, the implementation of improved maintenance system in the plant is expected as this study have shown that maintenance is a core function and essential in today's production system in order to reduce production losses, product defect and machine downtime, at the same time increasing production capacity and product quality to maximize company's profitability**.**

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Appendix A – The Brewery Process

In Dashen is a brewery company which the raw materials required for beer production is barley, hops (Gesho), water &yeast. The quality of these raw materials have a big influence on the quality of final product i.e. beer. Knowing the properties of the raw material, their effects on the process & product provides the basis for their handling and processing with such knowledge it is possible to control the whole process. The summary of the work flow (production process) has been shown in below diagram:

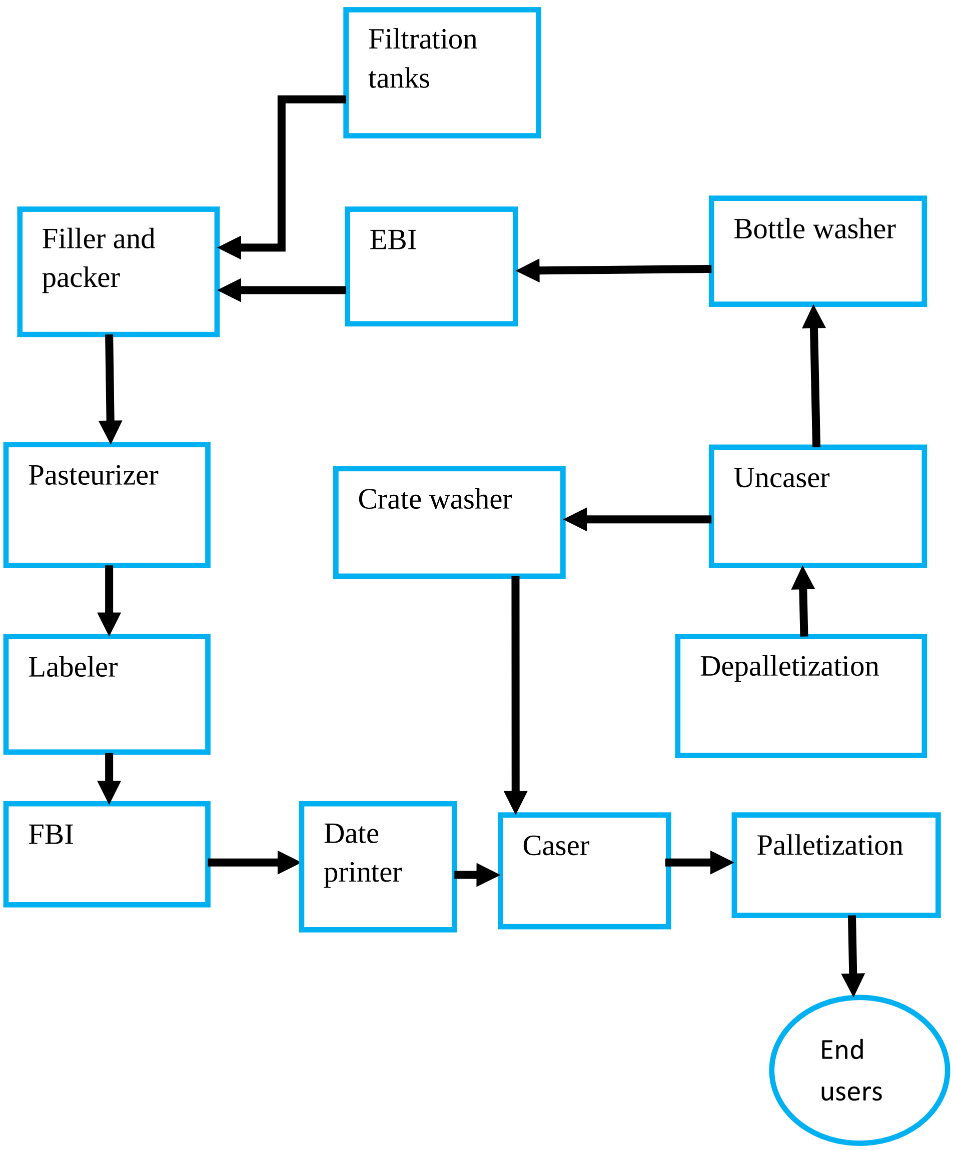

Figure A.1 Block diagram of production processes

Appendix B - Overall Organization of the Company

The organizational structure of Dashen Brewery Company looks as shown in figure

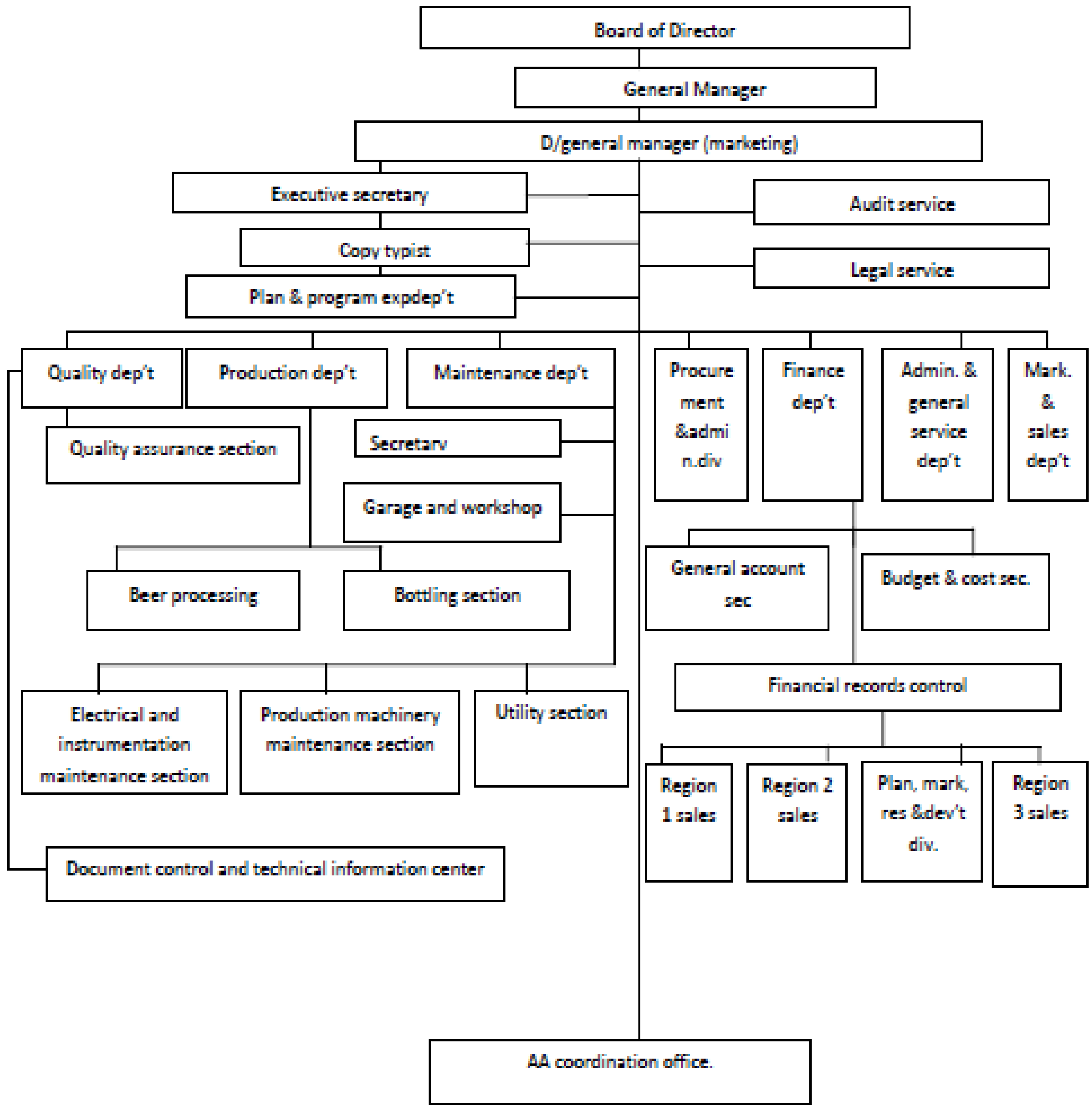

Figure B.1 Organizational structure of the maintenance department of DBSC

Appendix C – Questionnaires

The purpose of this questionnaire is to collect data related with the purpose of research in titled "Enhancing productivity through improved maintenance system'' by taking Dashen Brewery S.C as a center of attention for continuous productivity improvement through maintenance. The study focuses on assessing the existing maintenance system, identification of the root causes, prioritizing and proposes the solution for the maintenance problems.

Instructions

a. No need of writing your name

b. For Likert scale type statements and multiple choice questions indicate your answers with a check mark (√) in the appropriate block.

Section 1: Personal Information

1. Gender

A) Male B) Female

2. Age _____________

3. Marital Status

A) Single B) Married C) Divorced D) Other_______

4. Educational Level background

A) 10+1 D 10+4 G) Others (Specify)………………….

B) 10+2 E) Degree

C) 10+3 F) Masters

5. How many years of working experience do you have? ______________.

Section 2: Maintenance Department

After you read each of the statements, evaluate them in relation to your organization, and then put a tick mark (√) under the choices you prefer your priority.

Where, 5 = strongly agree, 4 = agree, 3 = undecided, 2 = disagree and 1= strongly disagree.

S.N	**Maintenance Organization**	5	4	3	2	1
1	The overall structure of the maintenance organization seem to be logical to accomplish the work in Dashen brewery S.C					
2	The management encourage maintenance to meet the needs of Production.					
3	The management support maintenance technicians and Production operators to work together on problems.					

4	Maintenance technicians follow safety policies and procedures when they do their tasks					
5	The industry support to continuous improvement efforts					

S.N	**Training Programs within Maintenance**	5	4	3	2	1
1	Training concerning new technologies are provided frequently to the maintenance craft employees at your Company					
2	Scheduled training programs are given on maintenance					
3	Maintenance craftspeople in the plant are properly skilled to do their jobs.					
4	**C**raftsmen take training to help themselves to do their jobs properly					
5	You are familiar with the installed equipment of the company					
6	You think training programs are very important for effective Maintenance					
7	The organization have low cost and accessible training facilities					
8	The organization have well trained and experienced craftsmen					

S.N	**Maintenance Planning and Scheduling**	5	4	3	2	1
1	The total amount of work orders have been delayed due to poor or incomplete plans (previous year)					
2	Responsibility for planning the preventive work orders relies on maintenance planner					
3	The industry have programs to evaluate the effectiveness of the maintenance that is carried out					
4	You set priorities for maintenance job tasks					
5	The equipments are maintained within a short time when the equipments failed.					
6	When the maintenance job is completed, the craftsmen that performed the job reports the actual working time, used material, and downtime.					
7	You planned shutdowns for major repairs in advance					
8	You have appropriate spare parts for maintenance					

S.N	**Preventive Maintenance**	5	4	3	2	1
1	The organization use work orders for preventive maintenance activities					
2	The preventive maintenance program cover critical equipment					
3	The maintenance program periodically review preventive maintenances for accuracy and training needs					
4	The operators help in cleaning equipments					
5	The operators help in lubricating equipments					
6	The operators help in adjusting equipments					
7	The operators help inspection of equipments					
8	The organization has track record how much it costs (Life Cycle Cost) to maintain equipment					
9	The organization tries to prevent breakdowns and failures from recurring					
10	The organization have an evaluation mechanism for the performance of preventive maintenance					
11	The organization have a schedule for periodic preventive maintenance					
12	The organization has an inspection team to check the actual condition of equipment.					

S.N	**Maintenance Inventory and Purchasing**	5	4	3	2	1
1	There is an availability of critical spare parts in the store					
2	There is a control in the maintenance inventory of spare parts					
3	There is an indicator of maximum and minimum levels for specified stored materials					
4	There is a permanent supplier of spare parts					
5	There is an appropriate management system for spare parts					

S.N	**Reliability Engineering**	5	4	3	2	1
1	There is failure analysis conducted by the use of an analysis tool such as fishbone, tree, five why's or Pareto, to assure accuracy and standardization for each analysis					
2	There is overall equipment evaluation calculated to monitor the condition of critical equipment					
3	The machines perform their required function for the specified time					
4	You have a method which increases reliability of machines					
5	The organization believe that improving maintenance could increase the reliability of production system					

S.N	**Production Efficiency**	5	4	3	2	1
1	The production focuses on maintenance practice					
2	Stoppage of production has a huge impact on the organization					
3	There is frequent machine downtime					
4	Machine downtime reduces designed or planned production capacity					
5	The level of machine downtime affects total production time					
6	In your brewery company unexpected maintenance cost happens highly					

1. In the time of downtime which methods used to enhance production capacity?

____

____

2. How you measure your maintenance capacity and performance?

____

____

አዲስ አበባ ዩኒቨርሲቲ

አዲስ አበባ የቴክኖሎጅ ኢንስትቲዩት

የሜካኒካል እና ኢንደስትሪያል ምህንድስና ት/ቤት

ኢንደስትሪያል ምህንድስና ድህረ ምረቃ ት/ክፍል

ተመራማሪ : ማህሌት ምንተስኖት

አድራሻ : mahiletme@gmail.com

ስ.ቁ : 0918789612

መጠይቅ

ውድ መላሾች የዚህ መጠይቅ ዋና አላማ በዳሸን ቢራ ፋብሪካ ዉስጥ በተሻሻለ ጥገና ዘዴ ምርታማነትን ለማሳደግ መረጃ ለመሰብሰብ ነዉ::ጥናቱ ትኩረት የሚያደርገዉ አሁን ያለዉን የጥገና ዘዴ ማጥናት፣ ዋና መንስኤውን መለየት፣ ለጥገና ችግሮችን ቅድሚያ መስጠት እና መፍታት ነዉ:: ስለሆነም ትክክለኛ ምላሽ በመስጠት እንድትተባበሩኝ እንጠይቃለሁ:: መልስዎ በሚስጥር እንደሚያዝ አረጋግጥልዎታለሁ::

ማሳሰቢያ

- **በመጠይቁ ላይ ስም መፃፍ አያስፈልግም::**
- **መልስዎትን በሳጥኑ ውስጥ የእርማት ምልክት (√) ያስቀምጡ::**

ክፍል 1: የግል መረጃ

1. ፆታ ሀ. ሴት ለ. ወንድ
2. እድሜ ________
3. የጋብቻ ሁኔታዎ ሀ. ያላገባ ለ. ያገባ ሐ. የፈታ መ. ሌላ__________
4. የትምህርት ደረጃዎ
   - ሀ. 10+1 ሠ. ዲፕሎማ
   - ለ. 10+2 ረ. ዲግሪ
   - ሐ. 10+3 ሰ. ማስተርስ
   - መ. 10+4 ሸ. ሌላ________

5. የስራ ልምድዎ _______________

ክፍል 2: የጥገና ክፍል

ከዚህ በታች የተዘረዘሩትን መለኪያዎች ካነበባችሁ በኋላ ከእርስዎ ድርጅት ጋር በማያያዝ ከተዘረዘሩት ችግሮች የእርስዎን የስራ ዘርፍ ላይ ይበልጥ ተፅእኖ የሚያሳድሩትን በደረጃ ያመላክቱ፡፡ ለእያንዳንዱ ጥያቄ ከአማራጮቹ ላይ አንድ ጊዜ ብቻ የ(√) ምልክት በማድረግ ምላሽ ይስጡ፡፡

5 = በጣም እስማማለሁ 3 = ለመወሰን እቸገራለሁ 1 = በጣም አልስማማም

4 = እስማማለሁ 2 = አልስማማም

MO		1	2	3	4	5
1	የዳሽን ቢራ ፋብሪካ አጠቃላይ የጥገና ክፍል መዋቅር ስራዎችን ለማከናዎን የተስተካከለ ነዉ					
2	አስተዳደሩ የሚፈልገዉን የምርት መጠን ለማግኘት ጥገናን ያበረታታል					
3	አስተዳደሩ የጥገና ባለሙያዎችንና የምርት ሰራተኞችን ችግሮች ላይ እንዲሰሩ ይደግፋል					
4	የጥገና ባለሙያዎች ስራቸዉን ሲሰሩ የደህንነት ህጎችንና መመሪያዎች ይከተላሉ					
5	ድርጅቱ ቀጣይነት ላለዉ እድገት ድጋፍ ያደርጋል					

TPM		5	4	3	2	1
1	የጥገና ሰራተኞች አዳዲስ ቴክኖሎጅዎችን ለመተግበር የክህሎት ስልጠና ይሰጣል					
2	ጥገና ላይ የስልጠና ፕሮግራሞች በእቅድ ይሰጣሉ					
3	በፋብሪካዉ ዉስጥ የጥገና ባለሙያዎች ስራቸዉን ለማከናዎን በትክክል ብቁ ናቸዉ					
4	የጥገና ባለሙያዎች ስራቸዉን ለማከናዎን እዲረዳቸዉ ስልጠና ይዎስዳሉ					
5	በፋብሪካዉ ዉስጥ የተተከሉትን መሳሪያዎች በደምብ ያዉቁታል					
6	የስልጠና ፕሮግራሞች ለዉጤታማ ጥገና አስፈላጊ ነዉ ብለዉ ያምናሉ					
7	ፋብሪካዉ ዝቅተኛ ዋጋና ተደራሽ የሆኑ የስልጠና መሳሪያዎች አሉት					
8	ፋብሪካዉ በደምብ የሰለጠኑና ልምድ ያላቸዉ ባለሙያዎች አሉት					

MPS		5	4	3	2	1
1	አጠቃላይ የስራ ትዕዛዝ ላለፉት ዓመታት በደካማ ወይም ባልተሚላ እቅድ ምክንያት ዘግይቷል					
2	የቅድመ ትዕዛዝ ሀላፊነት በጥገና እቅድ አዉጭዉ የተመረኮዘ ነዉ					
3	ፋብሪካዉ የተሰሩ ጥገናዎችን ዉጤታማነት መመዘኛ ፕሮግራም አለዉ					
4	ለጥገና ስራዎች ቅድሚያ መስጠት ላለባቸዉ ጥገናዎች ቅድሚያ ትሰጣላችሁ					
5	ማሽኖች ብልሽት በሚገጥማቸው ወቅት ባጭር ጊዜ ተጠግነው አገልግሎት ላይ ይውላሉ					
6	የጥገና ስራ ሲጠናቀቅ ባለሙያዉ የተሰራበትን ሰዓት፣ የተጠቀመዉን እቃ እና ስራ ያቆመበትን ሰዓት ሪፖርት ያደርጋል					
7	ለትላልቅ ጥገናዎች ቅድሚያ ለመዘጋት እቅድ አላችሁ					
8	ለጥገና በቂ የሆነ የመለዋወጫ አቅርቦት አለ					

PM		5	4	3	2	1
1	ድርጅቱ ለቅድመ ጥገና ስራዎች የስራ ትዕዛዝ ይጠቀማል					
2	የቅድመ ጥገና ፕሮግራሙ ዋና መሳሪያዎችን ያካትታሉ					
3	የጥገና ፕሮግራሙ በየጊዜዉ የቅድመ ጥገናዉን ትክክለኛነትና የስልጠና አስፈላጊነትን ይቃኛል					
4	የምርት ሰራተኞች የማሽን ፅዳትን ይረዳሉ					
5	የምርት ሰራተኞች የማሽን ዘይት መቀባትን ይረዳሉ					
6	የምርት ሰራተኞች ማሽኖችን በማስተካከል ይረዳሉ					
7	የምርት ሰራተኞች ማሽኖች ላይ ፍተሻ ያደርጋሉ					
8	ፋብሪካዉ ለ ማሽን ጥገና የሚወጣዉን ወጭ መመዝገቢያ ዘዴ አለዉ					
9	ፋብሪካዉ የማሽን ስብራትንና ብልሽትን አስቀድሞ ለመከላከል ይሞክራል					
10	ፋብሪካዉ ለቅድመ ጥገና ብቃት የምዘና አሰራር ዘዴ አለዉ					
11	ፋብሪካዉ በተወሰነ ጊዜ የሚደረግ የቅድመ ጥገና እቅድ አለዉ					
12	ፋብሪካዉ ማሽኖች ያሉበትን ሁኔታ የሚያረጋግጥና የሚፈትሽ ቡድን አለዉ					

MIP		5	4	3	2	1
1	በቂ የሆነ የዋነኛ መለዋወጫ ዕቃዎች አቅርቦት በክምችት ክፍሉ አለ					
2	በጥገና መለዋወጫ ክምችት ክፍል ዉስጥ ቁጥጥር አለ					
3	ተመርጠው ክምችት ክፍል ዉስጥ ለተቀመጡ ዕቃዎች ከፍተኛ እና ዝቅተኛ ደረጃ መለያ ዘዴ አለ					
4	ቋሚ የሆነ የመለዋወጫ ዕቃዎች አቅራቢ አለ					
5	ተገቢ የሆነ የመለዋወጫ ዕቃዎች አያያዝ ዘዴ አለ					

RE		5	4	3	2	1
1	የማሽን ብልሽት ጥናት ለማድረግ የጥናት መሳሪያዎችን（ fishbone, tree, five why's or Pareto）ይጠቀማሉ					
2	የዋነኛ ዕቃዎችን ሁኔታ ለመቆጣጠር የማሽኖች ምዘና አለ					
3	ማሽኖች የሚፈለገዉን ዓላማ ለተወሰነ ጊዜ ያከናዉናሉ					
4	ማሽኖች ያለብልሽት እንዲሰሩ የሚያደርግ ዘዴ አላችሁ					
5	ድርጅቱ በተሻሻለ የጥገና ዘዴ ምርታማነትን በመጨመር ያምናል					

PE		5	4	3	2	1
1	ምርታማነታችሁ ጥገና ላይ ትኩረት ያደረገ ነዉ					
2	የምርት ማቆም በድርጅቱ ላይ ከፍተኛ ተፅዕኖ አለዉ					
3	ማሽኖች በተደጋጋሚ ይቆማሉ					
4	የማሽኖች ብልሽት አጠቃላይ የምርት ጊዜዉን ይጎዳዋል					
5	የማሽኖች ብልሽት የታቀደዉን የምርት መጠን ይቀንሳል					
6	በድርጅቱ ዉስጥ ያልታሰበ የጥገና ወጭ በከፍተኛ ደረጃ ይከሰታል					

1. ማሽኖች በሚበላሹበት ጊዜ የምርት መጠንን ከፍ ለማድረግ የምትጠቀሙት ዘዴ ምንድን ነዉ？

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2. የጥገና አቅማችሁን እና ብቃታችሁን እንዴት ነዉ የምትለኩት？

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Appendix D – Down Time Data

Table D.1: Downtime on packaging, 2014

Causes of DT	**Percent % to the Total Downtime**												
Mechanical DT	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	Ave.
Filler	34.8	91.0	56.1	20.2	19.1	11.9	20.5	21.3	39.5	23.7	12.1	24.5	31.2
Labeler	18.7	16.4	34.2	28.4	19.9	8.3	15.3	21.9	19.3	19.2	11.5	8.9	18.5
EBI	0.3	0.4	0.2	0.0	1.2	0.2	0.2	0.2	0.3	1.5	1.2	0.2	0.5
Pasteurizer	8.4	3.1	9.3	3.2	7.5	3.7	13.5	6.6	7.4	12.0	4.9	1.7	6.8
Caser	6.5	20.2	15.4	8.6	13.3	5.6	5.9	7.1	5.9	9.9	9.7	3.1	9.3
Uncaser	0.8	2.8	12.0	7.3	6.7	3.2	0.0	1.9	4.4	2.0	3.3	5.1	4.1
Bottle Washer	5.7	39.1	44.4	31.3	9.9	5.2	6.1	27.8	2.8	5.1	2.2	7.9	15.6
Crate Washer	0.1	0.4	4.3	2.1	0.7	0.2	0.3	1.5	0.4	0.6	0.3	1.3	1.0
Empty BC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Full BC	0.0	0.0	0.0	0.0	2.7	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.2
Total Mech. DT	37.0	31.5	54.2	58.7	47.0	56.1	46.4	45.2	41.5	47.0	31.8	52.6	45.7
Electrical DT													0.0
Filler	4.4	12.7	15.7	2.8	1.9	33.4	6.3	11.3	9.2	6.2	8.8	5.9	9.9
Labeler	10.5	15.7	13.2	2.8	22.5	4.2	11.9	8.7	5.8	10.2	8.8	3.1	9.8
EBI	2.6	6.8	19.8	8.1	5.7	3.0	10.8	1.7	18.2	8.5	3.7	3.5	7.7
Pasteurizer	1.1	37.4	10.2	4.2	4.7	7.4	9.3	4.1	2.0	4.6	2.6	1.7	7.4
Caser	1.2	16.9	7.5	2.8	11.8	3.5	9.7	1.7	1.4	3.1	4.7	0.2	5.4
Uncaser	0.6	9.8	0.6	3.2	4.2	3.2	51.7	1.9	3.9	3.9	2.2	1.2	7.2
Bottle Washer	4.8	0.7	33.0	17.9	0.9	1.3	0.2	2.0	9.8	1.8	0.3	6.6	6.6
Crate Washer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.1	0.0
Empty BC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	0.0	3.2	0.1	0.7
Full BC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.0
Total Elec. DT	7.1	26.7	18.6	30.3	22.6	38.1	40.3	25.8	37.0	23.9	23.7	22.3	26.4
Total Operational DT	11.8	21.0	0.8	1.5	0.8	0.0	5.0	13.0	8.0	9.3	26.8	4.5	8.5
Others	44.1	20.8	26.40	10.0	29.6	5.80	8.3	16.3	13.5	19.8	17.7	20.6	18.0

Table D.2: Downtime on packaging, 2015

Causes of DT	**Percent % to the Total Downtime**												
Mechanical DT	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	Ave.
Filler	32.0	9.0	12.8	15.0	15.0	12.0	10.0	40.0	20.0	11.0	8.0	8.0	16.1
Labeler	14.0	24.0	23.7	15.0	17.0	16.0	17.0	19.0	37.0	8.0	9.0	9.0	17.4
EBI	0.0	1.0	4.3	0.0	0.0	0.0	1.0	2.0	2.0	0.0	0.0	0.0	0.9
Pasteurizer	4.0	9.0	3.7	3.0	5.0	5.0	9.0	11.0	7.0	3.0	8.0	5.0	6.1
Caser	2.0	4.0	3.1	8.0	8.0	8.0	4.0	11.0	14.0	6.0	9.0	7.0	7.0
Uncaser	5.0	5.0	3.3	5.0	9.0	7.0	11.0	8.0	10.0	2.0	4.0	3.0	6.0
Bottle Washer	49.0	4.0	2.6	28.0	11.0	16.0	12.0	11.0	11.0	25.0	42.0	5.0	18.0
Crate Washer	1.0	1.0	0.9	1.0	1.0	0.0	1.0	4.0	0.0	2.0	0.0	1.0	1.1
Empty BC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Full BC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Mech. DT	51.0	56.0	48.0	51.0	51.0	64.0	59.0	63.6	61.0	38.2	44.2	40.1	52.3
Electrical DT													
Filler	7.0	4.0	8.0	5.0	15.0	3.0	5.0	8.0	11.0	1.8	1.9	3.8	6.1
Labeler	10.0	10.0	9.0	9.0	7.0	11.0	10.0	45.0	29.0	3.2	6.8	7.8	13.2
EBI	11.0	22.0	9.0	9.0	10.0	11.0	10.0	21.0	22.0	11.5	6.1	12.1	12.9
Pasteurizer	7.0	4.0	4.0	3.0	2.0	4.0	6.0	11.0	18.0	2.4	3.2	4.7	5.8
Caser	2.0	1.0	2.0	1.0	2.0	1.0	0.0	5.0	16.0	1.7	2.9	0.7	2.9
Uncaser	3.0	2.0	1.0	14.0	2.0	0.0	1.0	5.0	3.0	0.5	0.2	1.3	2.8
Bottle Washer	1.0	0.0	9.0	7.0	1.0	6.0	7.0	1.0	1.0	0.7	0.2	0.2	2.8
Crate Washer	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.1	0.0	0.1	0.2
Empty BC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Full BC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Elec. DT	32.0	29.0	41.0	41.0	39.0	36.0	39.0	36.6	28.0	21.9	21.4	32.6	33.1
Total Operational DT	2.0	3.0	2.0	1.5	1.0	0.0	0.0	0.0	1.0	11.0	4.4	4.5	2.5
Others	15.0	12.0	9.00	6.5	9.0	0.00	2.0	0.0	10.0	27.9	30.0	22.8	12.0

Table D.3: Down time on packaging, 2016

Causes of DT	**Percent % to the Total Downtime**												
Mechanical DT	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	Ave.
Filler	13.0	9.0	23.0	16.0	19.0	19.0	12.7	26.0	16.0	14.0	8.0	21.0	16.4
Labeler	17.0	11.0	9.0	12.0	5.6	5.0	1.3	12.0	9.0	1.0	4.5	8.0	8.0
EBI	0.0	0.0	0.0	4.0	0.5	4.0	1.0	5.0	3.0	0.9	7.0	13.0	3.2
Pasteurizer	8.0	1.0	2.0	4.0	3.2	16.0	1.6	5.0	21.0	1.6	20.0	22.0	8.8
Caser	4.0	4.0	3.0	2.0	3.6	0.0	1.6	4.0	7.0	0.5	1.5	4.0	2.9
Uncaser	4.0	1.0	2.0	2.0	3.3	0.0	4.8	19.0	9.0	0.4	15.0	3.0	5.3
Bottle Washer	27.0	16.0	15.0	35.0	30.9	8.0	12.3	12.0	9.0	1.1	17.0	5.0	15.7
Crate Washer	2.0	1.0	1.0	0.0	0.6	3.0	1.4	1.0	2.0	0.2	1.0	9.0	1.8
Empty BC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Full BC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	0.0	1.0	0.3
Total Mech. DT	42.0	31.0	54.0	58.0	56.3	27.3	48.5	54.0	25.0	15.0	48.0	35.0	41.2
Electrical DT	0.0			0.0	0.0	0.0		0.0		0.0	0.0	0.0	0.0
Filler	2.0	4.0	2.0	1.0	1.9	6.0	1.8	11.0	15.0	0.8	1.4	1.0	4.0
Labeler	8.0	7.0	5.0	4.0	4.6	5.0	6.7	6.0	16.0	0.3	9.0	9.0	6.7
EBI	15.0	10.0	18.0	13.0	13.5	20.0	7.7	21.0	17.0	2.1	8.2	12.0	13.1
Pasteurizer	5.0	5.0	2.0	4.0	3.3	0.0	2.4	19.0	23.0	0.2	1.2	3.0	5.7
Caser	1.0	28.0	3.0	1.0	3.7	8.0	15.8	5.0	25.0	0.5	3.0	5.0	8.3
Uncaser	1.0	3.0	1.0	0.0	0.5	0.0	5.4	8.0	4.0	0.0	9.0	9.0	3.4
Bottle Washer	1.0	0.0	3.0	1.0	11.2	3.0	1.9	1.0	2.0	0.1	3.0	2.0	2.4
Crate Washer	0.0	0.0	0.0	0.0	1.3	0.0	0.2	0.0	1.0	0.0	2.0	0.0	0.4
Empty BC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Full BC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.0	0.0	0.0	1.0	1.6
Total Elec. DT	28.0	48.0	34.0	24.0	41.7	33.3	26.9	36.0	53.0	5.0	23.0	23.0	31.3
Total Operational DT	9.0	6.0	0.0	6.0	0.0	20.3	11.6	0.0	12.0	40.0	9.0	19.0	11.1
Others	21.0	15.0	11.00	12.0	0.0	18.00	13.1	10.0	10.0	40.0	21.0	3.0	14.5

Table D.4: Downtime on brew house, 2014

	Jan		Feb		Mar		Apr		May	
Causes of Down Time	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
Mechanical Down Times	2,370	25.4	30	0.9	0	0.0	4,480	74.0	2,183	28.8
Electrical Down Times	1,049	11.2	190	6.0	2,070	18.9	510	8.4	490	6.6
Total Operational Down Times	0	0	0	**0.0**	0	0.0	0	0.0	0	**0.0**
Others	5925	63.6	2960	93.8	8900	81.13	1061	17.8	4887	64.58
Total down time	9344	100	3180	100	10970	100	6051	100	7567	100

Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Total	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
50	3.0	135	1.1	0	0.0	1,340	25.9	290	6.8	0	0.0	945	26.8
505	30.6	35	0.3	325	6.2	0	0.0	90	2.1	185	4.6	0	0.0
0	**0.0**	0	**0.0**	0	**0.0**	0	**0.0**	0	**0.0**	0	**0.0**	0	**0.0**
1090	66.26	11750	98.57	7165	93.82	4220	81.6	3909	91.14	3849	95.41	2585	73.23
1645	100	11921	100	8490	100	5174	100	4289	100	4034	100	3530	100

Table D.5: Downtime on brew house, 2015

Causes of Down Time	Jan		Feb		Mar		Apr		May	
Causes of Down Time	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
Mechanical DT	793	9.2	47	2.0	60	1.3	590	4.9	365	3.4
Electrical DT	1,727	20.1	163	7.1	890	19.9	300	2.5	1,655	15.5
Total Operational DT	0	0	0	**0.0**	0	0.0	0	0.0	0	**0.0**
Others	6061	70.6	2085	90.5	3523	78.96	11110	92.6	8620	81.01
Total Down Time	8581	100	2295	100	10970	100	12000	100	10640	100

Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Total	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
210	2.5	240	4.4	275	3.3	315	6.1	160	4.2	510	11.5	25	0.3
1,375	16.1	115	2.1	535	6.5	650	12.3	50	1.3	795	17.9	0	0.0
0	**0.0**	0	**0.0**	0	**0.0**	0	**0.0**	0	**0.0**	0	**0.0**	0	**0.0**
6169	72.24	3644	66.27	5255	25.12	1290	25.1	2736	72.36	3115	70.48	4455	99.44
8539	100	5499	100	6065	100	5135	100	3776	100	4420	100	4480	100

Table D.6: Downtime on brew house, 2016

Causes of Down Time	Jan		Feb		Mar		Apr		May	
Causes of Down Time	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
Mechanical DT	265	7.4	1,482	11.5	937	5.8	270	3.5	269	3.3
Electrical DT	65	1.8	195	1.5	1,507	9.4	0	0.0	1,325	16.1
Total Operational DT	0	0	0	**0.0**	0	0.0	0	0.0	0	**0.0**
Others	3223	90.7	11211	87	13604	84.77	2380	96.4	6632	80.6
Total down time	3560	100	12838	100	16048	100	7650	100	8226	100

Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Total	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
262	3.9	290	7.3	250	4.4	345	6.7	150	4.9	125	3.5	315	7.6
1,281	19.2	175	4.4	522	9.1	540	8.9	62	2.6	180	5.1	518	10.4
0	**0.0**	0	**0.0**	0	**0.0**	0	**0.0**	0	**0.0**	0	**0.0**	0	**0.0**
5125	76.85	3500	88.23	4950	88.5	5170	85.4	2800	92.96	3220	91.34	4125	83.19
6668	100	3965	100	5722	100	6055	100	3012	100	3525	100	4956	100

Table D.7: Downtime on utility, 2014

	Jan		Feb		Mar		Apr		May	
Causes of Down Time	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
Mechanical Down Times	24	6.1	32	4.4	75	20.6	62	30.1	8	8.8
Electrical Down Times	98	25.3	65	9.7	61	16.7	25	12.1	22	24.4
Total Operational DT **(Luck of air, shortage of water, shortage of steam, luck of CO_2)**	266	69	619	86.4	228	62.6	118	57.5	60	66.6
Total Down Time	388	100	716	100	364	100	205	100	90	100

Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Total	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
58	19.0	18	15.7	73	12.1	21	15.4	7	11.4	62	5.8	62	11.9
63	20.6	59	51.7	52	8.6	57	41.9	29	47.5	17	1.5	51	9.7
184	60.3	37	32.4	475	79.1	58	42.6	25	40.9	989	92.6	408	78.3
305	100	114	100	600	100	156	100	61	100	1068	100	521	100

Table D.8: Down time on utility, 2015

	Jan		Feb		Mar		Apr		May	
Causes of Down Time	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
Mechanical DT	72	6.6	57	16.2	49	8.7	51	2.7	105	6.5
Electrical DT	87	8.0	21	6.0	71	12.6	78	4.2	71	4.4
Total Operational DT **(Luck of air, shortage of water, shortage of steam, luck of co2)**	925	85	271	77.4	440	78.4	1708	93.0	1,434	89.6
Total Down Time	1084	100	350	100	561	100	1836	100	1610	100

Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Total	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
58	12.9	55	2.3	102	16.4	107	9.8	106	7.6	52	2.8	27	1.2
97	21.7	181	7.6	52	8.4	87	8.2	77	5.5	75	4.1	0	0.0
292	65.3	2,142	90.1	465	73.1	888	81.9	1,203	86.7	1,714	93.2	2,287	98.8
447	100	2376	100	619	100	1084	100	1386	100	1839	100	2334	100

Table D.9: Downtime on utility, 2016

	Jan		Feb		Mar		Apr		May	
Causes of Down Time	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
Mechanical DT	51	17.4	51	4.5	39	3.2	135	4.5	29	7.4
Electrical DT	29	9.9	78	6.9	0	0.0	29	0.9	0	0.0
Total Operational DT **Luck of air, shortage of water, shortage of steam, luck of co2**	212	73	994	88.5	1,143	96.7	2810	94.4	362	92.5
Total Down Time	292	100	1123	100	1182	100	2974	100	391	100

Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Total	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
18	13.2	75	2.6	29	3.5	58	2.3	29	4.3	105	6.9	53	20.5
25	18.3	0	0.0	85	10.4	0	0.0	0	0.0	53	3.5	78	30.2
93	68.3	2,799	97.3	703	86.0	2,417	97.6	634	95.6	1,335	89.5	127	49.2
136	100	2874	100	817	100	2475	100	663	100	1491	100	258	100

Table D.10: component down time, 2016

		Month												
no	Component	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total DT/hr
1	Filling valve	16	20	23	21	-	16	23	7	9	8	19	25	177
2	Stopper	-	5	-	4	-	11	6	7	-	6	7	-	46
3	Turning gear	9	22	-	-	1	9	8	7	2	16	9	7	99
4	Crowner	-	18	17	4	-	8	19	12	7	-	8	15	108
5	Infeed starwheel	-	-	2	-	6	5	-	-	7	-	3	-	23
6	Intermediate star.	3	-	-	-	5	-	-	2	-	7	-	1	18
7	Discharge star.	-	-	-	5	-	2	-	3	4	-	-	-	13
8	Centering bell	3	9	-	-	4	-	7	2	7	3	-	5	40
9	Lift cylinder	3	-	5	-	2	-	8	-	2	-	7	1	28