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Machine Productivity Improvement Through Maintenance (A Case of Berhanena Selam Printing Enterprise)

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BAHIR DAR UNIVERSITY

BAHIR DAR INSTITUTE OF TECHNOLOGY

SCHOOL OF RESEARCH AND GRADUATE STUDIES

FACULTY OF MECHANICAL AND INDUSTRIAL ENGINEERING

INDUSTRIAL ENGINEERING

Thesis On: Machine Productivity Improvement Through Maintenance

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By Mebrate Enyew

Advisor: Bereket Haile (Ph.D.)

May ,2022

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A Thesis Submitted In Partial Fulfillment Of Requirement For The Degree Of Masters Of Science In Industrial Management

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Declaration

This is to certify that the thesis entitled "Machine Productivity Improvement Through MaintenanceA Case of Berhanena Selam Printing Enterprise", submitted in partial fulfillmet of the reqirment for the degree of Master Of Science in Industrial Management under faculty of Mechanical And Industrial Engineering, Bahir Dar Institute Of Technology, is a record of original work carried out by me and has never been submitted to this or any other institution to get any other degree or certificates. The assistance and help I recived during the cources of this investigation have been duly acknoweledged.

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Approval of ThesissForDefence

I hereby certify that I have supervised, read and evaluated this thesis titled “Machine Productivity Improvement Through Maintenance A Case of Berhanena Selam Printing Enterprise” prepared by Meberate Enyew under my guidance. I recommend the thesis to be submeitted for oral defence.

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Co-Advisor’s name Signature Date

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Approval of Thesiss for Defence result

I hereby confirm that the changes required by the examiners have been carried out and incorporated in the final thesis.

Name of student: **Mebrate Enyew** Signature: date: 25/05/2022

As member of the board of examiners we examined this entitled "Machine Productivity Improvement Through Maintenance A Case of Berhanena Selam Printing Enterprise" by Mebrate Enyew. We hereby certify that the thesis is accepted for fulfillment the requirement for the award of the degree of masters of science in "Industrial Management".

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Abbreviations

BSPE---Berhanena Selam Printing Enterprise

CMMS ---Computerized Maintenance Management System

EPQ--Economic Production Quantity

FMEA ---Failure, Mode And Effects Analysis

FMECA ---Failure, Mode, Effect And Criticality Analysis

FTA --Fault Tree Analysis

HOZOPS --Hazard And Operability Studies

ICT ---Information Communication Technology

KPI--Key Performance Indicator

MTBF --Mean Time BetweenFailures

MTTR--Mean Time to Repair

OEE---Overall Equipment Efficiency

OPL --One Point Lessons

PC--Personal Computer

RBI ---Risk-Based Inspection

RCM ---Reliability Centered Maintenance

SPSS ---Statistical Package For The Social Sciences

TPM ---Total Productive Maintenance

WCP ---World Class Performance

WCS--World Class standard

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Abstract

The adoption of an effective maintenance conceptual framework to increase the productivity and overall equipment effectiveness of manufacturing equipment is the subject of this thesis. The company's focus on proactive and preventive maintenance methods is limited, as its documention of maintenance operations and events, skill gaps in technologicalmachinery maintenance, and the lack of a comprehensive and standard maintenance strategy.The average values of quality rate, performance, availability and Overall Equipment Effectiveness of the company obtained are 98%, 61%, 57% and 34% respectively which is low compared to the world-class standards of 99.9%,95%, 90% and 85%.This paper shows how an effective maintenance policy could influence machine productivity and profitability of the company. The productivity index of one printing machine could be improved by an increament of 0.03 and at list 2.07 million Birr per year, i.e. about 13.2% of the machine yearly maintenance budget, could be gaind as a result of the productivity improvement of one printing machine when the company used the proposed maintenance system. A good maintenance conceptual framework is a useful tool for a company to increase its performance and availability, which leads to higher Overall Equipment Effectiveness and productivity. The conclusion was made that implementing a good maintenance conceptual framework can reduce wasted production time, improve productivity, reduce losses, increase the company's competitiveness, reduce machine downtime, reduce maintenance cycle time, reduce machine setup time, increase machine life, and increase company profit.

Key Words : Maintenance, Productivity, Overall Equipment Effectiveness,Availblity and Performance

CHAPTER ONE

Introduction

1.1Background

Maintenance of production systems has become one of the most important aspects of the business environment in recent decades. The rise of global competitiveness has resulted in significant deviations in the operations of industrial organizations. The deviations had an impact on maintenance, making it even more critical to a company's success. One of the numerous developments in manufacturing organizations is the implementation of a maintenance philosophy. Supporting functions are used by enterprises to help them go forward with their operations. Maintenance is a significant portion of the operations that have an impact on production performance (Akao, 1990). Production processes are changing from manual to machine as automation and mechanization increase. Every industry is attempting to enhance productivity using various tools, techniques, systems, and philosophies. Today, the world operates in a single unified global market and is competitive. Several types of manufacturing industries use an improved maintenance system (Marvin A. Moss, 1985).To keep up with the expanding global competitiveness, maintenance's job must evolve. To put it another way, maintenance should not always be reactive, but rather proactive. There is a requirement for upkeep in this regard. Losses can be reduced when the correct systems, infrastructures, processes, and procedures are in place and continuously followed.The operation becomes more steady, with increased production output and consistently high product quality, this is referred to as a situations of outstanding repairs. It is not uncommon for firms to save up to 50% on maintenance expenditures by switching from a reactive to a proactive management strategy (Pun, 2002). One sign of an effective administration system is good repairs. Equipment maintenance expenses rise when compared to having no maintenance program, yet the output fulfills the requirements) divided by the amount of material that enters the system over a specified length of time (Lofsten, 1999).The relationship between productivity enhancement and maintenance is well kown, maintaining machinery properly enhances its performance and availability, resulting in increased output. The effectiveness of equipment is no longer restricted to availability, but also includes quality and efficiency. Relevance Due to its role in ensuring and improving machine availability, performance efficiency, product quality and fast delivery, as well as environmental and safety requirements, the impact of maintenance on business performance aspects such as productivity and profitability has increased indefinitely in recent times (Swanson, 2001).Therefore, this research focuses on improving the machine productivity of Berhanena Selam Printing Enterprise through a good maintenance conceptual framework by identifying the keycauses that have an influence on reducingcompany productivity.

1.2Statement of the Problem

Poor maintenance practices can cause problems in manufacturing plants, such as unplanned equipment breakdowns, machine downtimes, and frequent system failures(Bellgran, 2010).Maintaining equipment reliability and availability is critical in industry with a high level of maintenance problems.

Berhanena Selam printing enterprise is facing greater challenges as a result of frequent breakdowns and machines with limited life cycles. The organization lacks an effective maintenance management system, which has a negative impact on overall output. Maintenance is performed with less notice in the organization, resulting in a reducing machine availability. This has a direct impact on the company's productivity, product quality, delivery, and schedule, as well as its overall efficiency. According to information obtained from the company report, the quantity of production scheduled for various productions which are newspapers, magazines, security press, and various pamphletsare 345,426,660 ETB in 2018/2019, however the realquantityrecordedremained 302,867,318 ETB, indicating that the company only met 87 percent of the plan. Due to the poorrepairingactivity, the enterprise has remained facing reptative machine failure.According to the company report, in the year 2018/2019, the following four printing areas experienced scheduled production time and stoppage due to machine failures:

- From the planned manufacturing time of 13,450 hours in the wave offset printing section. The total amount of time lost owing to an unintentional machine failure was 8,462 hours.
- From the planned production time of 28,374.4 hours in the offset printing department. The total amount of time lost owing to an unintentional machine failure was 10,536.25 hours.
- From the planned production time of 42,346.34 hours in the security printing section. The total amount of time lost owing to an unintentional machine failure was 11,335.52 hours.
- From the planned manufacturing time of 21,630 hours in the letterpress printing division. The total amount of time lost owing to an unintentional machine failure was 9,545.75 hours.

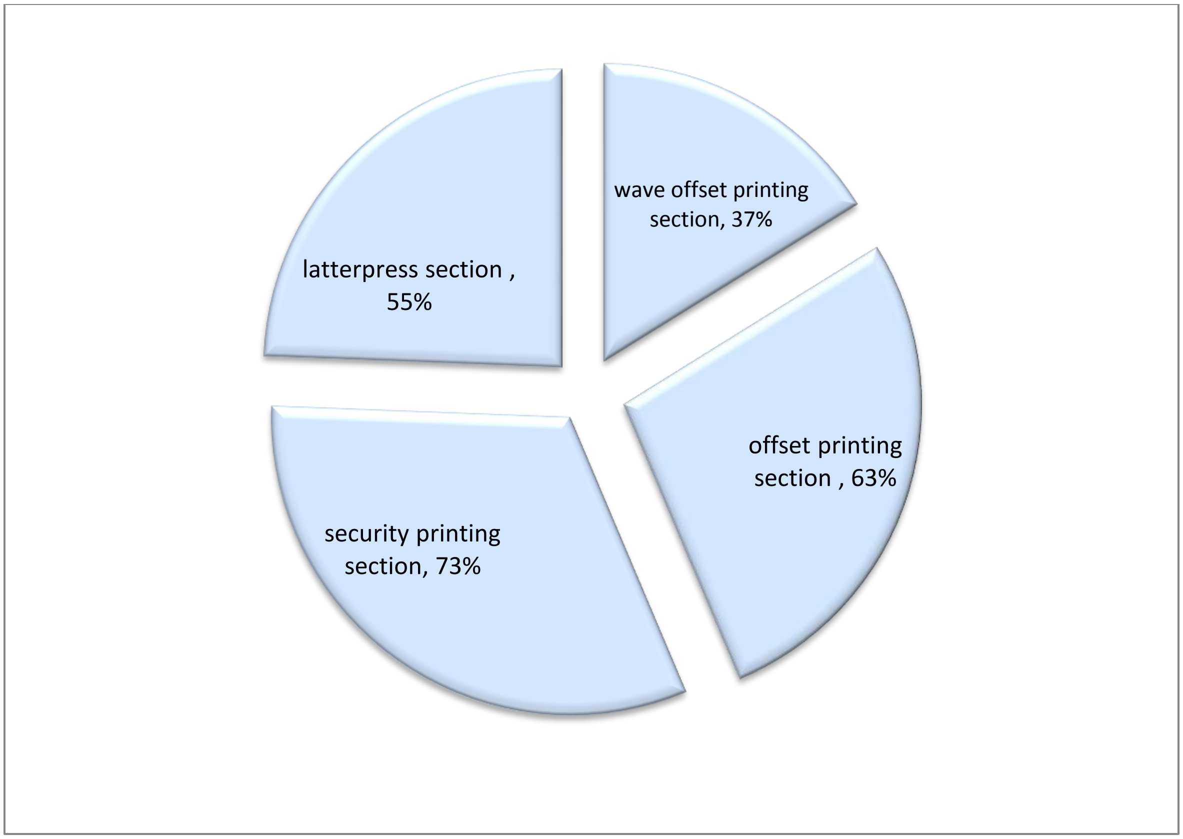


Figure 1:1: Effective time of the four productionareas (Enterprise yearly report)

The effective time of the four productionareas are as follows 37 percent, 63 percent, 73 percent, and 55 percent for offset, offset, security printing, and letterpress printing, respectively. In terms of non-productive time, the sections of offset, offset, security printing, and letterpress printing have 63 percent, 37 percent, 26 percent, and 44 percent, respectively.The value indicated that the organization has a high machine downtime incidence due to high machine failures. As a result, repeated machine breakdown are symptom of ineffective preventive upkeep, or the difficulty of maintaining machinery at the correct time and in the right place. This study focuses on increasing machine productivity through a company's effective maintenance system.

1.3 Research Questions

- What are the key problems in the company existing maintenance system?
- What factors contribute to the company of poormaintenance?
- How to enhance the productivity of the company through an improved maintenance system?

1.4 Research Objectives

General objective

The general objective of this study is to improve machine productivity by identifying the maintenance related problems and applying an effective maintenance system.

Specific objectives

The specific objectives of the study are as follows:

- To quantify the downtime and identify the major reasons causing it.
- To evaluate the Berhanena selam printing enterprise current maintenance system.
- To develop maintenance conceptual framework that improves maintenance system resulting in improved productivity

1.5 Significance of the study

The research provides both theoretical and practical maintenance management knowledge that can be applied to enhance the company's production. Top management of the printing and maintenance directors, maintenance officers, and researchers who want to undertake additional research on maintenance management to boost productivity will benefit in particular.

The company's top management will be able to compare their performance to that of similar printing companies. They will learn about their vulnerabilities in terms of maintenance management in their positions, and will be able to develop action plans to enhance productivity.

1.6 Scope of the Research

The study is being carried out in the Berhanena Selam printing enterprise with the goal of analyzing and improving production through maintenance management. Pre-printing, printing, letter press and post-printing are thefour sections of the case company. As a result, the research focuses on these four printing sections.

1.8 Organizations of the Research

The research consists of six chapters, the first chapter are introduction and background, statement of the problem,significance of the study, and socp of the study are all discussed. In chapter two literature related to the study are conducted. In chapter three research methodology, data collection and presentation methods, data analysi tools, sampleing, and are all covered in details. In Chapter four, the study cover data collection, presentation, and analysis. In chapter five, the study cover proposed results are presented and finaly chapter six, covers conclusions and recommendations of the study.

CHAPTER TWO

Literature Review

2.1. Overview of Maintenance

The purpose of all technical, administrative, and management actions conducted over an item's life cycle(Alsyouf, 2007).According to the European standardmaintenance is to keep a system/product in excellent working order for the duration of its lifecycle. As people become more aware that maintenance brings value to the business process, Companies consider maintenance to be an essential aspect of their operations. As a result, the efficiency of the maintenance process is important to many sectors' long-term value generation and profitability(Liyanage, 2003).It is critical to measure the effectiveness and efficiency of the asset, in order to take appropriate and corrective action risks in minimizing and mitigating security risks, complying with social responsibilities, and improving the asset's effectiveness and efficiency(Wireman, 1990).

In general, productivity is defined as the ratio of a manufacturing system's output to its input. The products or services delivered are the outputs of the production system, whereas production is made up of numerous resources such as personnel, materials, tools, plant and equipment, and others that are utilized to make the products or services(John, 1993).

The impact on other areas of work is also assessed when analyzing the economics of maintenance (for example, affirming the role of maintenance in gaining the life cycle of the machine)(Obamwonyi, 2010). Because general maintenance improvements are intended to lower operating costs while also enhancing product quality, the economics of each improvement activity may be comprehensively and continuously improving the efficiency, effectiveness, and productivity of the production process at a low cost. This can be accomplished by continuously maintaining and improving the quality of all the elements that contribute to the production process (Maletic, 2012).

2.2 Productivity Measurement and Factors

Productivityrefers to the efficiency of the production system and indicator to; how well the factors of production (land, capital, labor and energy) are utilized and defines several measures of the efficiency of production. A productivity measure is stated as the ratio of output to inputs used in a production process(Prokopenko & Joseph, 1999).The measure of productivity is defined as a total output per one unit of a total input. Productivity is a vital factor in the production performance of companies and nations. Increasing national productivity can increase living standards because more real income improves people's ablity to buy goods and services, enjoy leisure, improve housig and education and contribute to social and environmental programs. Productivity growth also helps businesses to be more profitable (Hubert, 1980).Productivity of each resource can be measure separately, such measurement gives single factor productivity. The technique of calculating productivity seeing more than one resource is called multi factor productivity approach to measuring productivity (Maletic, 2012).

2.3 Productivity Improvement

Productivity improvement is one of the most important factors for an organization to continuein this increasing competition. Globalization has given growth to new standards for products the customers have to be meet keeping the right standards for quality, varity and other factors that have become obligatory for the organization to have an edge over the others(Rana & Arif, 1997). Productivity improvement focuses on doing the right things by continuously needs. Doing things right by constantly improving production and distribution process to produce and deliver the goods and services in the most efficient way(Geert, 2002).

2.4. Maintenance and Its Impact on Business Process

Maintenancefunction has grown in prominence throughout time and has directly influence on product quality(Al-Najjar, 2004). Efficient maintenance adds value by maximizing resource use. The total losses caused by maintenance neglect or ineffectiveness have been highlighted by a number of academics and practitioners. Despite this, maintenance is quiet regarded as a cost center, according to aassessment of 118 Swedish business enterprises, which found that 70% of accused regard upkeep as a cost focus(Alsyouf, 2007).

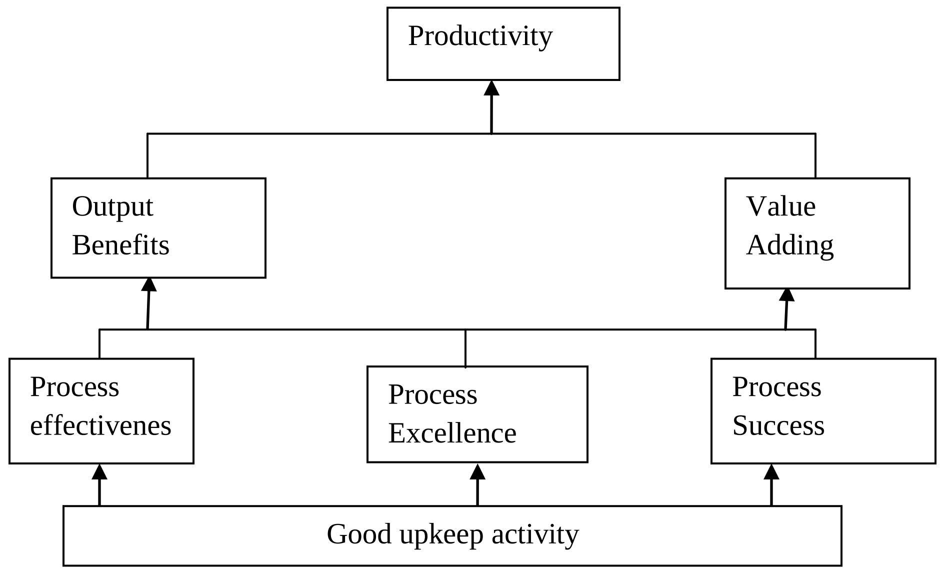


Figure 2.1: Impact of proper maintenance practices on company competitive advantage (Alsyouf, 2007)

2.4.1 Maintenance and Production

According to (Alsyouf, 2007)primary goal of production is to create items or products. Nonetheless, an effective maintenance strategy has an impact on the machine's production capacity for these items. As a result, maintenance can be thought of as an administrativetask that runs concurrently throughfabrication(Ben-Daya, 1995).Even though stating manufacturing creates manufactured goods, the writersimilarly state repairs creates production volume. As a result, maintenance has an impact on manufacture by enhancingvolume while simultaneously monitoringproductivity quality and excellence.

Although the importance of maintenance in achieving production goals has been highlighted in the literature, much work remains to be done in order to integrate maintenance and production because, in most models, maintenance is seen as a limiting constraint, and the question is how to meet the production master schedule when maintenance is a constraint (Ben-Daya, 1995). As a result, maintenance and production must be integrated on the basis of a clear understanding of their relationship. As a result, maintenance has an impact on output by increasing capacity and controlling quality and quantity.This is shown in figure 2.2.

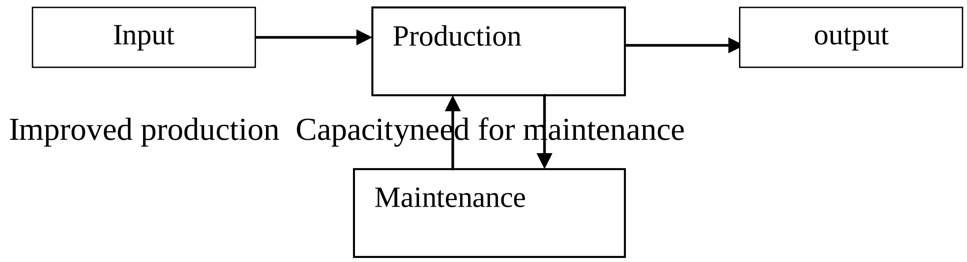


Figure2.2: The relationship between maintenance and production (Gits, 1994)

2.4.2. Maintenance and Quality

Effectiveness, on the other hand, cannot be accomplished without consistent product quality. In today's global market, value has remainedknown as the key to competitiveness and continuingproductivity(Madu, 2000). As a result, the importance of maintenance in this attempt cannot be overstated.

In general, machines/equipment that is not maintained and fails on a regular basis has speed loss or lacks precision, and hence produces flaws. Such machinery frequently causes industrial processes to spiral out of control(Arca, 2008)

As a result, an uncontrolled process is assured to yieldfaultyoutput while also increasing manufacturing costs, resulting in lower profitability, putting the organization's survival at jeopardy. This statement indicates that equipment maintenance and product quality are inextricably linked.

2.4.3.Maintenance and productivity

The effect on furtherfunctioningzones is also considered when evaluating maintenance profitability. Maintenanceenhancementsas a wholetarget to lower operating costs while enhancing product quality and productivity. As a result, the costeffectiveness of each enhancementaccomplishmentcan be assessed by comparing the essential cost controlformerly and later changes, according to a study conducted (Alsyouf, 2007).

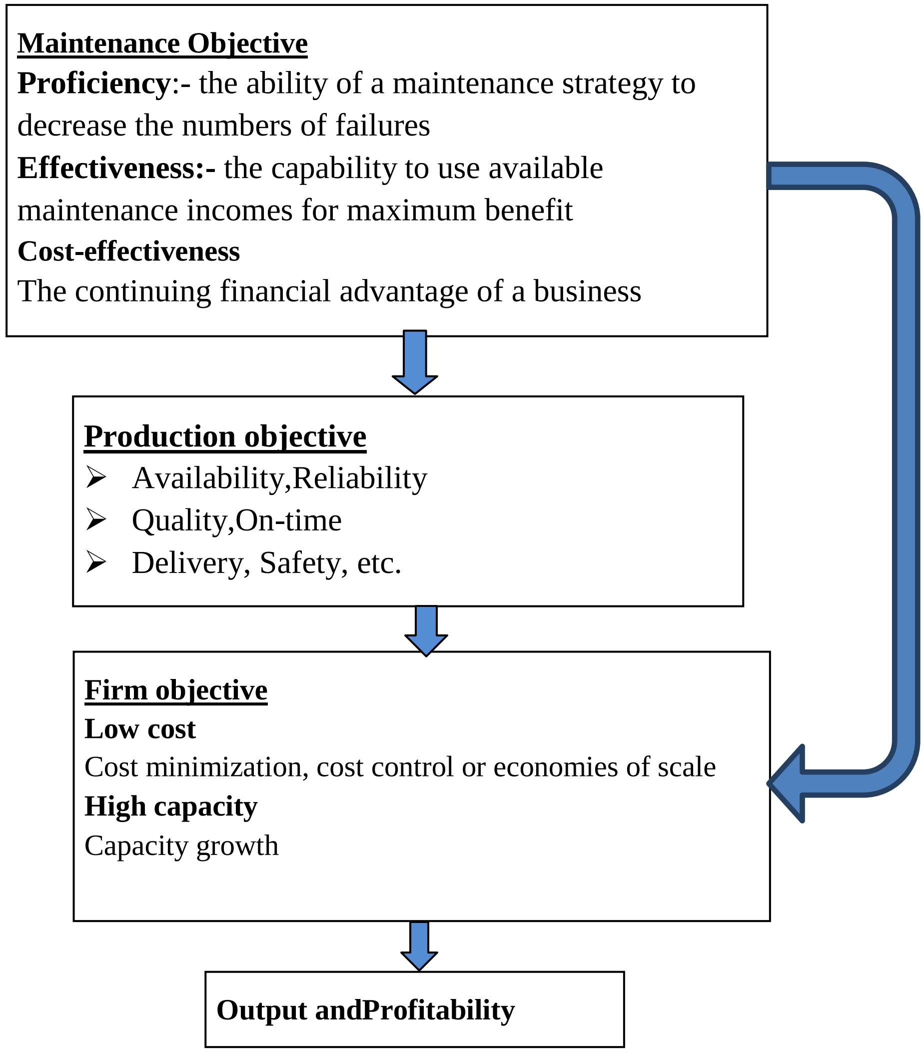


Figure2.3:Relationship between maintenance with profitability and output (Kans, 2008)

2.5. Maintenance Philosophies

Preventive maintenance which encompasses all scheduled maintenance operations such as condition monitoring and periodic inspection, and correct maintenance, which deals with any unplanned maintenance actions to recover from the defect, are the two main categories of maintenance(Blanchered, 2004).

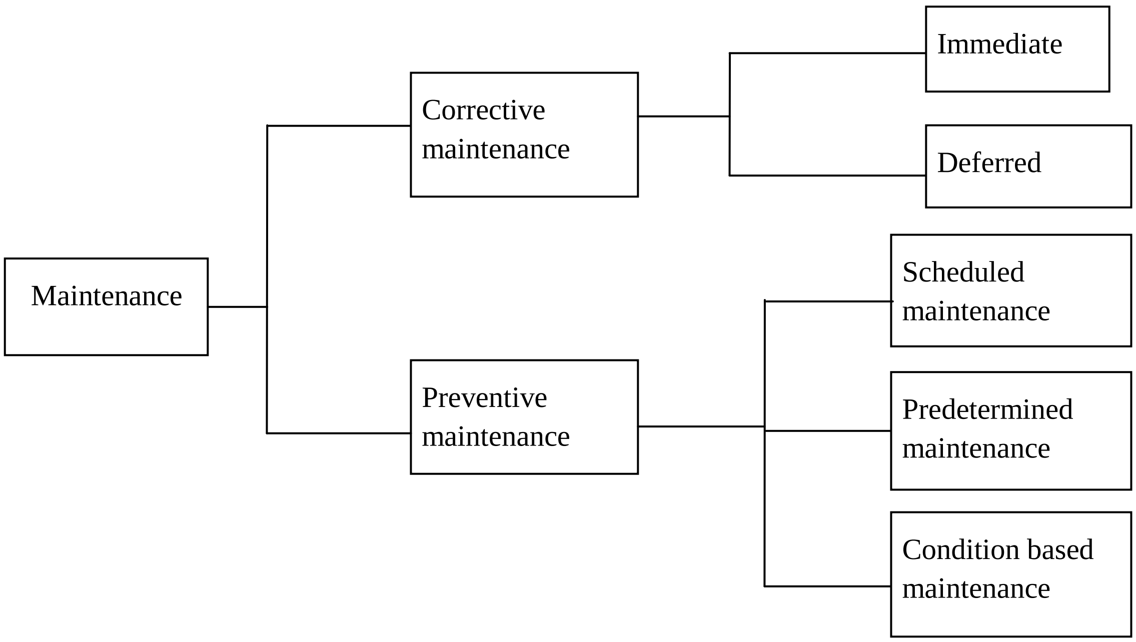


Figure 2.4:Different maintenance approachesoutline (Alsyouf I. , 2009)

a. Corrective Maintenance

A type of maintenance that’s performed subsequently a mistake has been identified and is designed to return an item to a state where it can accomplish a required task.

This maintenance style is plain and simple: "repair it when it breakdowns," that is, equipmentarestatic after or throughout failure. This can be an emergency, restor, unplanned, and corrective maintenance task. This methodremained used in maintenance since the first industrial plant was built, and it appears to be logical on the surface. However, there is no downtime, and product availability is minimal, with significant overtime labor expenses and spare parts inventory prices (Alsyouf, 2007).The remedial method waits until the equipment fails before performing any maintenance. Without any preventative maintenance, lubrication, or adjustments, this maintenance management strategy is rarely applied.

b. Preventive maintenance

Preventive maintenance entail changingparts or servicingthings at predetermined interims in order to avoid previousmachine failure and unplannedstoppage that are necessitate repairs. The method is mostly a periodic task that is carried out to maintain appropriate level of availability and consistency(Parida, 2007).

According to the Eroupian standards PM has three parts.

I. Scheduled Maintenance

Scheduled maintenance performed in accord with a predetermined timetable.

II. Time Based Maintenance(TBM)

Time based maintenance performed out of prior condition surveys and in accord with time or number of units usage intervals set.

III. Condition Based Maintenance

Condition-based maintenance is performed in response to a prediction obtained as of the investigation and assessment of importantconstraints of the thing's condition. Maintenance enhancement method described that has remained implemented to the number of businesses, both essentials established for separate efficiency and overall program participation(platfoot., 1997).

2.6 Maintenance Approach

To improve maintenance efficiency and concentrate on maintenance activities, several solutions have been developed. Run to failure (breakdown maintenance), Preventive (schedule) maintenance (PM), Predictive maintenance (PDM), Reliability Centered Maintenance (RCM), and Total Productive Maintenance (TPM) are some examples discussed here (TPM).

2.6.1Run to failure (breakdown maintenance)

Its underlying principle is to let machinery run until it breaks down, then fix or replace it when obvious issues arise(Visser, 2013).In the event of a breakdown, run-to-failure equipment remains static while being repaired, restored, or parts replaced.

2.6.2Preventive (schedule) maintenance (PM)

(Dillon, 2001), Short machinelifeowed to breakdown, a hugeamount of defects and discardsowed to untrustworthyequipment, an increase in machinemaintenancecosts owing to disregard in parts such as consistentgresing, checkup, and changing of damagedparts are some of the features of a firm that needs to apply preventive equipment maintenance.PM furthermore defined as the repair and service provided by technicians to retainmachine in aacceptable operating condition by allowing for methodical examination, finding, and adjustment of initial faults before they occur or evolve into catastrophic failures(Oliveira, 2014).

Preventive maintenance aims to extend the useful life of capital equipment, reduce important equipment breakdowns, reduce manufacturingdamagesowing to machinary failure, and advance the strength and care of techniciance staff.

2.6.3 Predictive maintenance (PDM)

Condition-based maintenance is another term for predictive maintenance. Maintenance is started with this technique in answer to a exact,machine problem or showing decline. (Alsyouf, 2007).

PDM is the process of controllingmachinaryfunctioningsituations in order to senseevery indicators of fault that could lead to a company's letdown. After the component wear has been recognized, it is closely monitored. Different monitoring and diagnostic procedures are encompassed in this methodology, including vibration monitoring, thermography, tribology, process parameters, visual inspection, and other nondestructive testing techniques. The benefits of predictive maintenance are limited by ineffective planning and poor repairs (Wireman, 1990).

2.6.4 Reliability Centered Maintenance

Maintenance that is reliability centric is done based on the likelihood of equipment failure and the cost of such failure. The capacity to detect issues long before they occur with reliability-centered maintenance ensures that the production process is disrupted as little as possible. It also prevents failures from occurring before they manifest (Attia, 2006).The process of determining and guaranteeing that any asset continues to operate as intended in its current state is known as reliability centric maintenance. Prioritizing maintenance on assets with high risk value in terms of safety and economics is a common maintenance technique. Maintenance with a focus on reliability is a strategy that is gaining traction around the world (Attia, 2006).

The basic goal of a reliability-centered maintenance program is to preserve system function and detect failure modes that potentially impair system function. According to the literature, if RCM procedures are properly implemented, they can cut normal maintenance work by 40-70 percent (Parida, 2007).

Maintenance with a focus on reliability identifies the company's most vital operations and then works to improve maintenance techniques to reduce system failures and, as a result, maximize machine dependability and accessibility. This maintenance method identifies likely failure mechanisms and their effects while keeping the equipment's function in mind.There are various recommended techniques for adopting reliability-centered maintenance, which are outlined here in Figure below.

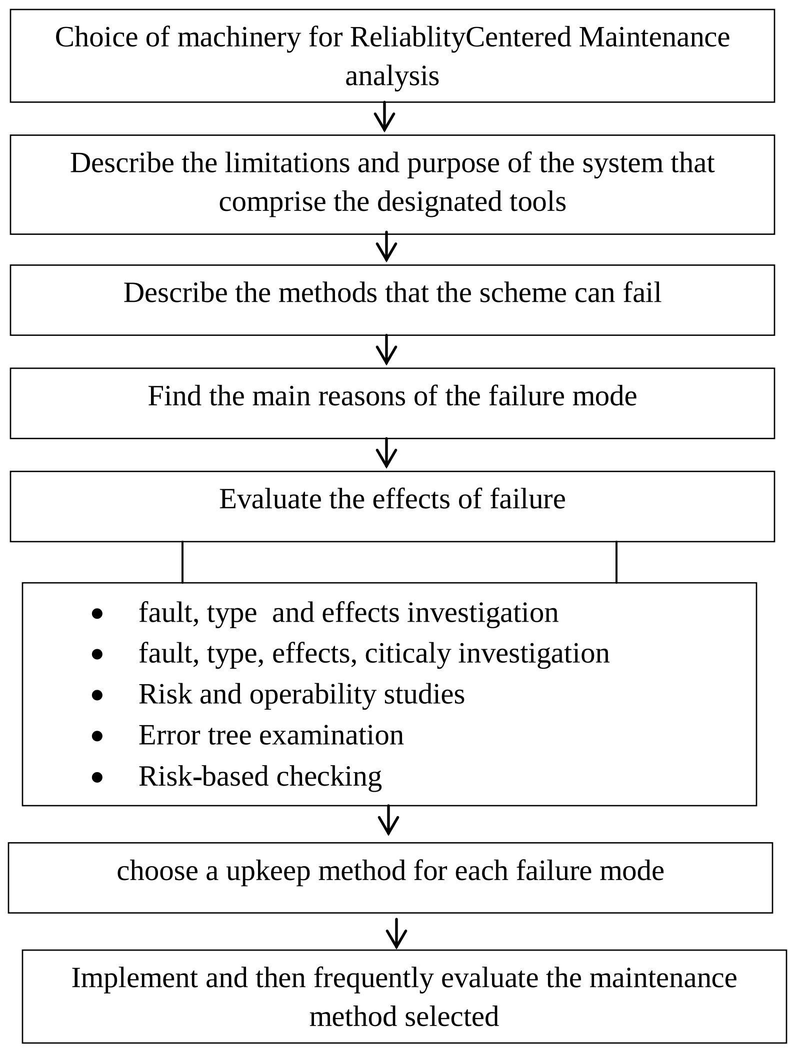


Figure 2.5: Steps for implementing reliability centered maintenance(Parida, 2007).

In short, RCM II's complexity and, as a result, its cost are two of its main drawbacks. The major goal is to achieve reliability rather than maintainability and availability. In avation sectors and technological businesses, such a strategy makes sense, but it's often too costly in other industries, where maintenance is more of an economic issue than a dependability issue (platfoot., 1997)

2.6.5Total Productive Maintenance

In Japan, the idea of Total Productive Maintenance was created in 1971 G.C to alleviate system maintenance difficulties by delegating greater responsibility to operators and personnel (platfoot., 1997). Total: denotes considering all aspects and involving everyone from top to bottom, as the term TPM says with three words. Productivity: a focus on trying to do it while production is running and minimizing production issues; and Maintenance refers to the autonomous upkeep of equipment by production operators in good working order, including repairs, cleaning, and greasing, as well as the willingness to spend the necessary time on it(Parida, 2007). Total Productive Maintenance is a manufacture-focusedenhancement process optimizes and guarantees employment or plant assets by involving people and combining manufacturing, maintenance, and engineering. As (Oliveira, 2014)This definition easily fits TPM as a whole.

As (Chandrahas, 2015)Total Productive Maintenance is a well-explained innovative Japanese idea for fractory and machine maintenance. Total Productive Maintenance is predicted to verify to be effective strategy for assisting manufacturingparts in improving their performance in reaching core competencies on a consistent basis. As a result, in today's highly competitive climate, TPM may be the most proactive initiative that can assist industrial firms in reaching new heights of achievement (Narayan, 2011).

Total Productive Maintenance focuses on maximizing Overall Equipment Efficiency with the participation of everybody in the company. It willn’tmerely set up comprehensive maintenance scheme, but it will similarly aim to increase the shop floor operators' maintenance abilities. Total Productive Maintenance and its ramifications have now achieved renowned international recognition for accomplishing the ultimate Zero Defects and Zero Breakdown goals.

2.6.5.1 Pillars of Total Productive Maintenance

The eight pillars of Total Productive Maintenance, according to researchers, laid the framework for organizations to attain world-class performance (WCP) (Sugumaran, 2014). The following are eight pillars of Total Productive Maintenance(Sugumaran, 2014):

Pillar One: autonomous maintenance

Autonomous maintenanceis the operator's duty to do main equipment upkeep. Cleaning, lubrication, and inspection are all part of the operators' routine maintenance. When it comes to assigning operators responsibility for routine maintenance, it's critical to teach personnel and develop their ability to be multi-skilled and self-directed. The differenceamongoperators and maintenance workers will remain bridged as a result of this. This simplifies the task and creates a cohesive team.According to (Narayan, 2011)to gradually raise operators' skill, contribution, and accountability for their machine.

Pillar Two: planned maintenance

To increase maintenance efficiency, such as predictive, preventive, and productive maintenance system is established. The following seven processes are carried out as part of the scheduled maintenance(Bhoyar, 2017.)Proper functioning, Proper set-up, Cleaning, Lubrication, Retightening, Feedback and repair and High-quality spare parts.

Pillars Three: focused improvements

This is about identity; the manager is responsible for implementing an organization-wide loss management system in order to enhance productivityvia reducing waste and productionlooses. The following are categories of production losses:

- Losses in machines
- Manpower shortages
- Losses in material

The following losses are included in each manufacturing loss under these three kinds of losses.

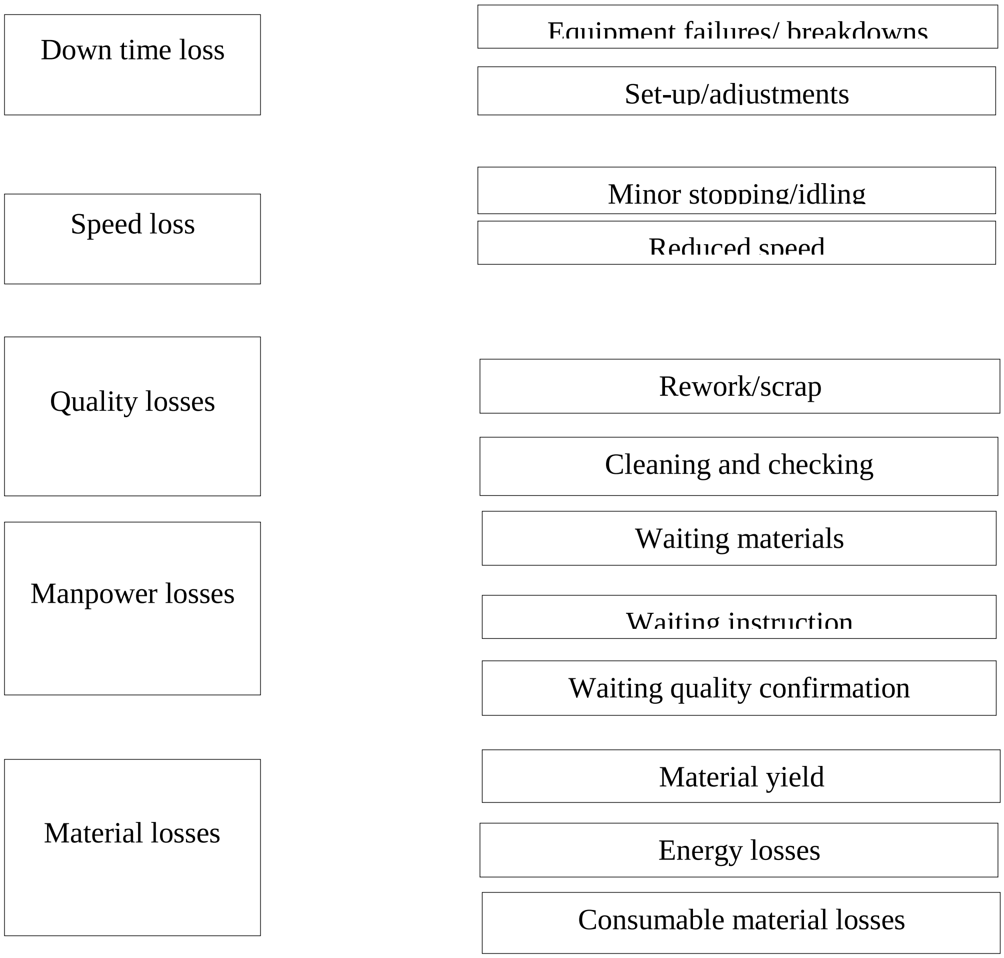


Figure2.6: Manufacturing losses (Bhoyar, 2017.)

It is intended to help companies achieve a zero-defect system by detecting and preventing errors in production processes. Root cause analysis is used to remove common sources of quality faults. Its goal is to identify machine factors that affect product quality and to improve product quality by concentrating on main causes of faulteliminationthen lowering the amount of faultexistences.

Pillar Five: Education and Training

It is all regarding putting together anability and training plan to help with Total Productive Maintenanceapplication. Operators, machine technician, and supervisors are all affected. Operators learn how to maintain equipment on a regular basis and spot potential problems. Maintenance workers are taught ways for performing productive and preventive maintenance. The goal of this pillar is to develop trained operators in order to improve their ability to solve existing difficulties at the bases(Andrews, 2012).

Pillar Six: safety and environment

It ensures that the working environment is harmless and well. It reduces possiblewellbeing and care hazards, making the workplace safer, and it is specifically designed to achieve the aim of an accident free workplace.

Pillar Seven: office TPM

It focuses on all parts of the organization that perform administrative and support responsibilities. TPM must be implemented across the entire organization for it to be effective. Manufacturing support functions, as well as administrative and support divisions, are included.

Pillar Eight: development management

This pillar explains how to create new items and arrangements in a short amount of time and at a minimal cost. Each stage, tool, and technique used in the development of a new machine or product must be precisely specified(Patil, 2018).

2.7 Comparisonof Maintenance

Rather of being implemented independently, several maintenance systems are combined to take advantage of their respective strengths in order to maximize facility and instrumentality irresponsibility while lowering life-cycle costs. Total productive maintenance (TPM), total maintenance assurance (TMA), preventative maintenance (PM), reliability center maintenance (RCM), and a variety of other creative approaches to maintenance challenges all strive to increase machine effectiveness and, as a result, production.

Table 2.1: Comparison of maintenance approach (Deepak & Jagathy, 2013).

Maintenance type	Explanations	Usage	Deficiency
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.	Potentially safety hazards and increased costs due to unplanned maintenance and associated downtime, overtime, spare parts and secondary damage.
Preventive	"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. Unplanned 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 cause 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 defined 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 affects 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".	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.

2.8.Maintenance Management

Equipment and facilities are made available by a good maintenance management system. Time and money are squandered if essential equipment or services are unavailable, or if a machine stops short of finishing a task. A solid maintenance management system aids in reducing downtime(Nilsson, 2006)

Maintenance policy, material control, work order system, equipment records, preventive and corrective maintenance, project planning and scheduling, backlog control and priority system, and performance measurement are all elements of successful maintenance management.

2.8.1 Maintenance Management and Operational Performance

To attain world-class performance, more firms are replacing reactive, "firefighting" maintenance tactics with proactive strategies such as preventive and predictive maintenance, as well as aggressive strategies such as total productive maintenance. Many operations also rely on effective maintenance. Because the performance and competitiveness of manufacturing organizations are based on the dependability, availability, and productivity of their production facilities, maintaining the productivity performance of plants and machineries in a dependable and safe working condition is critical. Equipment maintenance and system reliability are essential elements that affect an organization's capacity to provide quality and timely services to clients and to stay ahead of the competition, according to the authors. As a result, any manufacturing plant's maintenance role is critical to its long-term success (Alsyouf, 2007).

Maintenance is essential aimed atsubstantial and capital intensive businesses to improve their manufacturing systems to accomplish their longterm goals. In general, if maintenance is neglected in a production system, it is very likely that the system will produce faulty product as a consequence of aequipmentfault. As a result, maintenance is now more important than forever in achieving these goals. Indeed, effective maintenance not only helps to reduce life cycle costs, but it also contributes to the company's overall performanc(Denscombe M. , 2002).

Accordingly to (Bellgran, 2010), Maintenance management entails tasks such as planning, organizing, implementing, monitoring, and regulating in order to maintain a system's and its components' (assets') availability, value, and reliability, as well as its capacity to operate to a given standard degree of quality. As a result, the maintenance management practice chosen has a significant impact on the firm's success(Denscombe M. , 2002).

According to (Bellgran, 2010), Maintenance costs in modern manufacturing and construction companies are often significant, accounting for 30 percent of overall operating costs.This cost is projected to be higher in electrical power producing enterprises. In order to lower organizational operational expenses and increase organizational efficiency and effectiveness, it is critical to pay particular attention to maintenance measures, measurement, and management.According to (Renjit, 2011), Technical, economic, safety, and human resources are the most commonly utilized maintenance performance metrics. They found that training/learning, skills/competencies, work incentives, process performance, resource utilization, maintenance capacity, customer happiness, and employee satisfaction were the least used measures.It should be remembered that maintenance, quality, and productivity are not mutually exclusive. They stated that by improving total equipment effectiveness through correct and adequate maintenance of machinery and equipment, quality and productivity can be improved. They went on to say that productivity measures how well a company's maintenance, quality, and production processes are operating as a whole(Gupta, 2005).

2.9. Role of maintenance in manufacturing performance improvement

As (Chandrahas, 2015)According to their research, maintenance is important not only for protecting the health of equipment in a facility, but also for fulfilling an company's objectives and goals with minimal maintenance costs and increase output. The “total asset life cycle optimization,” or maximization of plant/equipment availability and reliability in order to fulfill operational/business objectives, is one of the fundamental goals of maintenance management. As a result, maintenance involves a mix of management, operations, technology, and business strategy, rather than just dealing with technical concerns (Arca, 2008).

Maintenance has always been viewed as a non-productive support activity because it does not directly create revenue (Aziz, 2013). To thrive in this high-stakes global competition, an organization's ability is determined by how successfully it adapts to changing market demands in order to please customers. Manufacturing firms' performance and competitiveness are dependent on the availability, dependability, and productivity of their production facilities. This means that in order to be competitive, a company must analyze and manage elements such as reliability, quality, flexibility, and availability to meet demand, as well as delivery. Other departments, such as production planning and control, personnel management, and material acquisition, must be included in addition to maintenance management.

2.10. Maintenance Trend Globally

Maintenance has usuallyremainedbelieved as a distinctunit from production procedure. There was a gradual shift in thinking as corporations started to appreciate importance of maintenance in the manufacturing procedure(Chandrahas, 2015). Several processes rely on effective maintenance. Extends the device's service life, enhances its availability, and ensures that it is in great working order. Poorly maintained equipment, on the other hand, might result in more frequent equipment breakdowns, lower equipment utilization, and production schedule delays (Oliveira, 2014). Machine and instrument reliability and availability are critical considerations for competitiveness, especially in applications where safety and availability are critical(Csaba Horvath, 2010).Numerous maintenance sections are embracing Personal Computer's and connected technologies such as Computer Maintenance Management System software even today, as technology is increasingly being integrated elsewhere in enterprises (R.Peach, 2016). The industry's international competitiveness can remainenhancedvia creating innovative strategies and techniques for more precisely and convincingly specifying and controlling product reliability (Csaba Horvath, 2010). However, in today's maintenance officer, things are rapidly changing. Modern technologies are being used by smart, proactive maintenance managers to forecast, manage, and monitor maintenance activities(Andrews, 2012).Process, product, customer expectations, suppliers, and competitiveness have all influenced manufacturing industry evolution.

2.11. Maintenance Trend in Ethiopia

Maintenance has go through a paradigm change in recent decades; it's no longer viewed as aessentialwicked, but rather as an important element of industrial process that adds value to the company(R.Peach, 2016).Though, that mindset still remains in Ethiopia ss(Lemma, 2013)According to their research, the majority of Ethiopia's industries are unknown, and no structuredform that everything on maintenance and it's quiet in early stages in the nation.

In general, industrial companies function at less than their projected capacity for a variety of reasons, one of which is a high rate of unplanned failures, which is evident in our country. When it comes to industry performance, there is a common perception that once a company is profitable, it is functioning well. It was costly to perform maintenance tasks according to a schedule and in advance of a breakdown.Insufficientschedule maintenance is related to low output, stoppage, and poor machine performance, all of which lead to decreased production, more costs, and fewer profits.

The majority of Ethiopian manufacturing industries do not attempt to apply proper decision-making procedures in order to uncover hidden costs related with manufacturing losses, machinestoppage, and equipment performance. According to(Chandrahas, 2015), The type of maintenance strategies used on a machine determines its performance. Machine breakdowns can result in output losses, thus manufacturing businesses must consider effective maintenance methods for their machinery. When maintenance activities are correctly done, the performance and availability of the machines are maximized, resulting in higher productivity. Maintenance's influence on companyoutput characteristics for examplethroughput and productivity has maximized in recent years as a result of its involvement in assuring and increasing machine availability, performance efficiency, product quality, and other factors.In our country, it is clear that most industries pay little or no attention to assessing performance and productivity. Because the things that need to be improved can't be seen, they're buried. As (Lemma, 2013)TPM is a significant new means in successful overall industries with the best performance over the selected period, according to the idea of Total Productive Maintenance in Ethiopian production industries, which is an acutely lost concept in effectively attaining not merely world-class machineefficiency but similarly a significant new means in successful overall industries with the best performance over the selected period. This means that much more work must be done to raise awareness and modify industry attitudes around maintenance.

2.12Maintenance in Printing Industry

In order to maximize production and revenues, organizations must implement effective maintenance practices. Because there is an obvious link between productivity, dependability, and maintenance, this is a critical issue. Effective maintenance is critical in the printing business to ensure that equipment performs at its best and that production is consistent. Fast technological and financial changes have created a completely new resposiblity for printing companies maintenance divisions(Csaba Horvath, 2010). Printing technology has advanced significantly in recent years, necessitating careful consideration.

Maintenance that is done correctly can save total operating costs, assure planned completion, in additionsafeguardreliable productionexcellence. Though, numerous Ethiopian company'squiet use a responsivemethod to upkeep, focusing solely on equipment when it breaks down.

2.13. Key maintenance performance indicators

A key performance indicator is a quantifiable and strategic determinateassessment that shows a business's crucial achievement aspects. It is difficult for any company to evaluate performance in meaningful ways and make changes to solve performance-related concerns without KPIs. Industries must determine which process areas require the greatest attention; otherwise, they will have no idea how they are doing. Maintenance performance indicators can be measured using a variety of metrics.According to (Aziz, 2013) Mean Time Between Failures, Mean Time to Repair, and OEEare the most important KPs. One of the important performance metrics a manufacturing organization can use to measure its performance is overall equipment effectiveness is one importantant performance meteric a production company can use to measure its performance.

2.14.Maintenance Performance Measurement

An company can always devote significant money and effort to evaluating its performance and determining its success. The literature on performance measurement highlights the need of maintaining relevant assessments that continue to represent business challenges (Gits, 1994).

Most firms, on the other hand, give little or no attention to integrating their performance measurement system with their organizational hierarchy levels and the various measurement criteria related to external and internal stakeholders, as well as the operational process (Parida, 2007).

2.14.1. Maintenance Cost

Maintenance-related costs in general, are commonly separated into direct and indirect costs without taking into account maintenance savings and profit(Al-Najjar, 2004).Costs associated with outsourcing maintenance activities are classified as direct and indirect costs.(Al-Najjar, 2004)In addition, mention to direct maintenance expenses that are straight related to maintenance operations, such as internal expenditures essential to conveythe maintenancepurpose, such as employee, equipments, replacement portions, education, and additionalrepairscosts.

All expenses that remainnot directlylinkedthrough maintenance are indirect expences, such as income loss owing to manufacturing losses throughoutscheduled and unexpectedbreakage, client losses, standing, as a result, market share loss as a result of maintenance-related factors (Denscombe M. , 2002).

2.15Maintenance Management Tools and Techniques

Industrial businesses have understood and recognized maintenance management technologies. Because equipment maintenance and reliability are critical tactics that have a big influence on a business's capacity to accomplish tasks efficiently, they must measure and assess its system using a variety of tools and techniques.

According to (Visser, 2013)Overall Equipment Effectiveness (OEE), Pareto Analysis(PA), One Point Lessons (OPL), 5s Training, Continuous Improvement, Autonomous Maintenance(AM), and Poka Yoke (PY) are selectedmethods used to assess and resolvemachine and procedureassociateddifficulties.

Overall Equipment Effectiveness

Overall equipment effectiveness is a measurable statistic that is progressively being utilized in manufacturing schemes for managing and controlling production equipment efficiency, additionalyit's indication and activator of method and performance enhancements(Tsarouhas, 2013). It's a useful method measuring equipment performance that considers the six key losses: downtime, machine failures, setup and adjustments, speed losses, idling and minor stoppages, and defect losses.

Machine accessibility, performance rate, and quality rate are measured through maintenance performance indicators. Many companies realize the importance of OEE in determining bottom-line outcomes, and it talks losses caused by machine defects. The Overall Equipment Effectiveness is a metric for assessing maintenance efficiency. Since, begins throughoverallfundamentals(i.equality, productivity, and availability), the model is arranged in anorganizedmanner(platfoot., 1997). One advantage of OEE is that it gives a standard repairscreativitythrough combining three functional and significant areas into one concise figure. To determine "availability, performance, and quality rate," a derivative of OEE was utilized.

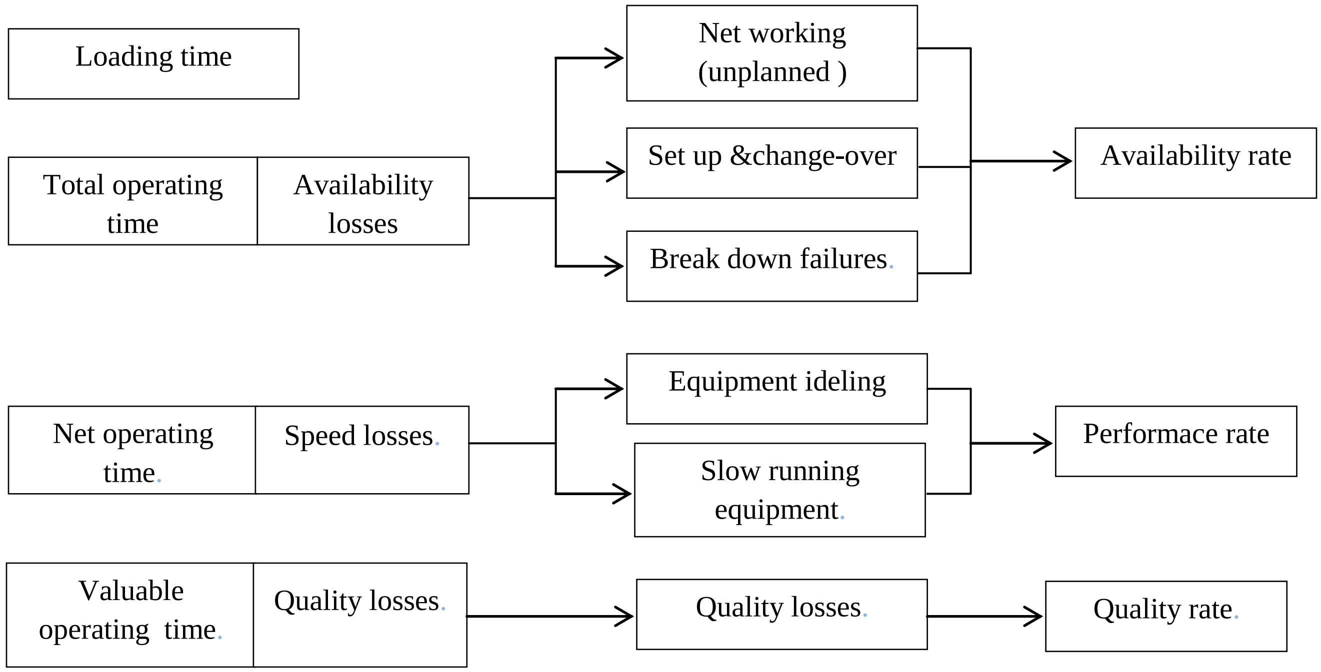


Figure 2.7: Maintenance Metric Overall Equipment Effectiveness(Tsarouhas, 2013).

The following are downtime losses;

$$\boldsymbol{Availablity = \frac{loading\ time - downtime}{loading\ time} * 100}$$

The next are the speed losses which affexts performance of machines,

$$\boldsymbol{Performace = \frac{process\ amount - defect\ amount}{processed\ amount} * 100}$$

The quality of the product employed in the creation of the output is referred to as the process quantity.

The actual cycle time is the measured time between two good quality products produced in practice(Stamatis, 2011).

A system's operating time is the amount of time it works in a way that is satisfactory to its production workers.

The final losses are quality problems losses,

$$\boldsymbol{Quality\ rate = \frac{process\ amount - defect\ amount}{processed\ amount} * 100}$$

Scrap quantity refers to the quality of a product that is not used in the manufacturing process.

The above allthree factors mentioned help to determine the OEE meteric, therefore;

$$OEE = Availability * Prformance\ rate * Quality\ rate$$

90% availability, 95% performance efficiency, and a 99% quality rate are the minimum requirements (Levitt, 1996). A benchmark OEE of 85 percent is give thought to worldclass performance. Nonstop defect procedures should have an Overall Equipment Effectiveness of 90 percent or greater, whileconstant stream processes would have an Overall Equipment Effectiveness of 95% or higher (Hanssan, 2002).

Cause and Effect Diagram (Fishbone Diagram)

The cause and effectchart is a methodical method delving into the details of a problem to determine the source of variance and gaps. According to the research of (Herry, 2018), the cause and effect diagram has five primary components that generate problems. These are man, machne, methods, raw materials, and work environment.

2.16. Literature Summary

The summary is looking into existinggood practices in repairs in order to compare the efficiency of the BSPE's present maintenance scheme. Based on case studies in linked industries, the research attempts to recognizeproblems in existing maintenance approaches and giveusefulunderstandings and recommendations to enhance maintenance approach.

The following literatures, which were gathered from many authors, are valuable for gaining a well understanding of the maintenance system and for identifying the gaps quickly.

Table2.2: literatures summary.

No	Literatures list	Objective	Technique	Result
1	(Melesse workneh wakjira, 2012)	To evaluate the contributions of TPM	TPM	increase equipment's availability
2	Lemma, 2013	Developed and proposed maintenance system	Used qualitative and quantitative data	Established and suggested maintenance scheme also implementation of TPM scheme to preserve the results of model
3	Aziz, 2013	Recognizedaccidental machine failur,	(ABC)investigation to identify most significantsections for a proper planning system for implementing TPM	Focuses on the implementation procedure of focused improvement
4	(Kumar, 2017)	Developed a failureexamination to finddivision wise and particular equipment	Break down analysis	Maximum breakdowns happened and recommend corrective action & preventive actions for particular machines
5	(Maletic, 2012)	To study the role of maintenance in improving firm's competitiveness	Assessment collected from a Slovenian textile company and (CBM)	Around 3 % of additional profit could be generated at weaving machine
6	(Alsyouf, 2009)	To examine the	Survey within	The goal of maintenance

		maintenanceactivities that are used in Swedish industry	Swedish firms, (TPM) and Reliability Centered Maintenance	isn't highly known
7	Afefy, 2010	Worthwhile maintenance of the firm components natural reliability value	RCM	22.1percentyearly spare parts cost are saved when suggestedPM
8	(Kelly, 1984)	In maintenance principles should haveplanning and scheduling	Survey and questionnaire	clearfailure of everyrepair principles to plan and schedule
9	(Shelke, 2001)	To indicate effect of implementing TPM in business; in brewery firm	Total Productive Maintenance	Improved availability with average enhancement of 2.25 percent
10	(Tsarouhas, 2013)	Examines the association b/n the plant management &the process	Descriptive statistic on machine and Overall Equipment Effectiveness	improved productivity and efficiency by improving PE and QR
11	(Olayinka, 2000)	Study the production performance of a beverage manufacturing plant	TPM	Increased OEE by 50%
12	(European committee for standardization CEN, 2006)	To gives a clear indication of how important a maintenance strategy is	Survey and questionnaire	Include the most appropriatekind of maintenance, workforce, time and place for attaining the maintenance objectives

2.16.1 Literature gaps

The literature review identified a number of research papers dealing with maintenance and its impact on a business'seffectiveness and productivity. Many researchers worked on maintenance challenges, and to answer them, concentrated on several maintenance strategies for example, Total productive maintenance(TPM), reliability-centered maintenance(RCM), and condition-based maintenance(CBM).Despite this, the importance of maintenance effects on a company's business is underlined; a review of the literature revealed that few previous research examined maintenance impacts on a firm's productivity in Ethiopia's printing industry. As a result, the goal of this study is to understand the role of maintenance in enhancing a firm's success and consistency, as well as to address the pressing issue of machine productivity in the Berhanena Selam printing enterprise.

Using a good maintenance framework, the effects of maintenance difficulties and their impacts on the efficiency of the printing firm remained analyzed in this thesis, andbestanswer in providing a positive modification to the maintenance difficulties was provided.Since good maintenance is a decision-making tool, processes and maintenance plans can help both the processes and outcomes involved. Good maintenance practices have been proven to reduce equipment malfunctions, minimize small stops, reduce excellence flaws and dues, increase output, lower worker and expenses, downsize inventory, reduce accidents, and encourage worker participation.

The action of creating good maintenance flow-charts benefits everyone involved in the process by encouraging improved collaboration. The flow-chart increases knowledge of the system's function, the repercussions of failure, and the economics of operating and maintaining it. The best maintenance technique provides a medium of communication, and therefore a viable bridge between theory and practice (Moss, 1985).

CHAPTER THREE

Research Design and Methodology

3.1Research Method

The way we approach challenges and seek answers is referred to as methodology(Steven J. Taylor, 1984).It is also a method of conducting research that includes numerous data collection approaches, processes, and instruments for data analysis. It focuses on the most effective ways to learn about the world(Denzin, 2000). This section provides an overview of the research methods used.

3.2 Data Collection

The sources of data utilized in this study namely primary and secondary data sources. Under this two methods used in this research are literature review, company documents, interview, questionnaires, and observation.

3.2.1 Primary data collection

Priamary data is collected through questionnaires from maintenance workers, production workers, maintenance and production team leader and directors of the company.

a) Observation

In order to understand the facts about the case company actual production process i.e. how exactly the exsiting system is working, maintenance activities used, the situations that the company doing things, how techniciancs perform their maintenance routines and other things related to maintenance activities have been observed.

b) Interview

Interview has been conducted with production and maintenance director, maintenance team leader, engineering experts and some high level maintenance tecniciance and production workers.

c) Questionnaire

A questionnaire is a text-based written form of an inquiry (Robson, 1993)"Questionnaires" are written questions that can be self-administered by the researcher or sent by mail, according to the definition. The researcher created questionnaires on the topic of maintenance, which was chosen for this study, as well as other connected topics. The questionnaires were created and classified according to the level of positions, such as high leveladministration, maintenance team leader, engineering expertise, maintenance experts, and production workers. Data for the Likart scale was gathered using a structured questionnaire response that was dispersed proportionally to the sample size. The poll asked 140 employees to complete the questionnaire,This figure was selected from a total of 274 people in the production and maintenance departments. This study's questionnaire is made up of seven main components and 39 key questions, totaling four pages. There were five categories of responses on the questionnaire: Strongly Agree, Agree Unsure, Disagree, and Strongly Disagree. The table shows that the reliability and validity were cheeked, and Cronbach's Alpha was 0.953, which is higher than 0.7. As a result, it's acceptable.

Table 3.1: Reliability analysis and checking.

Case Processing Summary.

		N	%
Cases	Valid	115	100.0
	Excluded	0	.0
	Total	115	100.0

Reliability Statistics

Cronbach's Alpha	N of Items
.953	39

3.2.2 Secondary data collection

Secondary data were obtained from different books, newspapers, megazines, academic papers, reports, etc. in addition to these, written literatures were used to enhance the data. The researcher has also used weekly, monthly and annually production reports, planned and actual production time and machine downtime of the company.

3.3 Sampling frame and sample size

A sample frame is a complete list of individuals of the target population (Bethlehem, 2012). Random, non-random, and mixed sampling approaches are among the types of sampling techniques used in this study. Purposive sampling is used instead of random sampling. This style of sampling is particularly beneficial for constructing a historical reality, describing a phenomenon, or developing anything about which only a small amount of information is available. In qualitative research, this sampling approach is increasingly common. This technique can also be applied to qualitative research (Renjit, 2011).In quantitative research, the purpose of the sample is to draw inferences about the group from which you selected the sample. It is appropriate for this investigation for the reasons stated above.

Sample size: The maintenance department employs a total of **45** people. As a result, completely maintenance and engineering personnel involved in data collection. Because the population of production departments is so large that it is impossible to investigate everyone, the following equations are employed to generate suitable sample size that helps the studyoutcomes.

According to (Othman, 2014) to get sample size of production worker below formula can be used:

$$no = \frac{z2xp(1-p)}{c2} \ldots\ldots 1 \quad nf = \frac{no}{1+\frac{no-1}{N}} \ldots\ldots 2$$

The letters can be denotes inthe following way:

no = initial sample size nf = target sample size

Z, denotes, z-values for confidence level are (1.645 for 90 percent confidence level, 1.96 for 95% confidence level and 2.576 for 99 percent confidence level)

P,denotesfraction picking a choice, expressed as decimal 0.5 used for sample size needed

C,denotes confidence interval, expressed as decimal; 0.08=±8

N, denotes population=230 workers (regular and security printing section supervisor and operators)

$$no = \frac{(1.960)2x0.5(1-0.5)}{(0.08)2} \ldots\ldots 150.06 nf = \frac{(150.06)}{1+\frac{(150.06)-1}{230}} = \mathbf{90.986 \sim 91}$$

Hence, the numbers of participant of production workers(operators) in the data gatheringare**91** and **4** staffs from the high leveladministrator members selected.

Therefore, the total numbers of participants for the data collection are**140.**

3.4 Data analysis tools

The acquired data must be examined in order to obtain the desired outcome from the study. Different tools and methods for analyzing data have been employed in various studies; it might be software or any other means. To produce a meaningful result, tools and approaches must be chosen as needed(Tsarouhas, 2013).As a result, the researcher used a variety of tools to examine the data acquired through questionnaires and company records in this study.

3.4.1.Overall equipment effectiveness

OEE is a quantitative statistic that is becoming more common in manufacturing systems for regulating and monitoring production equipment productivity, and alsothe indication and driver of process and performance improvement(Tsarouhas, 2013).It's one of the maintenance performance metrics since it measures all losses in three categories: availability, performance, and quality. As a result, the OEE calculation was adopted in this study since it provides an essential role in monitoring machine availability, performance rate, and quality rated, as well as addressing all losses caused by equipment failures.

3.4.2 Cause and effect analysis (root cause analysis)

(Wilson, 1993), Defined an analytic tool that can be utilized to conduct a system-wide and comprehensive review of major incidents. It's a well-known tool for identifying, sorting, and displaying potential reasonsfor a certain difficulties. It examining the reasons for recurring machine failure while taking into account various circumstances. Causes and effect analysis was utilized in this study because of its benefits in discovering the fundamental cause of specific problems.

3.4.3.Statistical package for the social sciences

Statistical package for social scienes (SPSS) is the best widely used software, with a wide range of applications and roles. This program is used to examine the information gathered from questionnaires.

3.5. Validity and Reliability

3.5.1. Validity

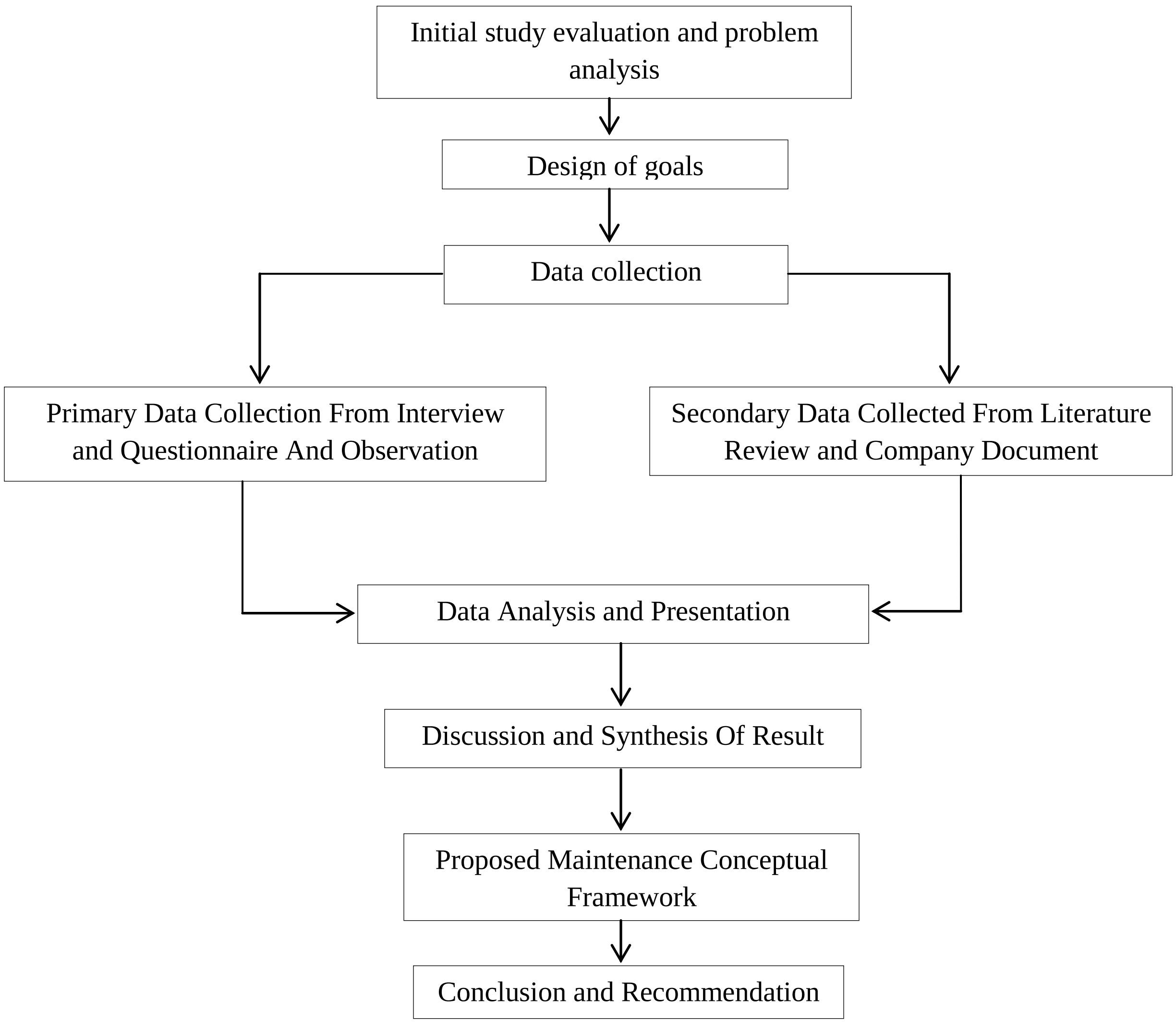
(Bjereld, 1999), Validity is defined as "the degree of agreement between the theoretical and operational definitions." This just signifies that the researcher looked into what was supposed to be looked into. When the precision of the presented material (data, analysis, and questions) in the study is high, it is said to have good validity.To achieve high validity in a study, the researcher should use correct, non-interpretable, and relevant data and conduct an analysis (Denscombe M. , 2002).

3.5.2 Reliability

It is critical for the researcher to be able to trust the tools and procedures employed in the investigation (Denscombe M. , 2002). The researcher conducted a reliability test in order to create robust and consistent study outcomes. Chronbach Alpha statics is the most frequent technique for evaluating the scale's reliability and stability. It is the most often used method for assessing reliability and stability in the literature. According to (H/Mariam, 2018)A Chronbach alpha reliability coefficient of 0.7 or above is regarded satisfactory. When Chronbach alpha is 0.7 or higher, 0.8 or higher is better, and 0.9 or above is optimal.

3.5.3 Research Framework

The graphical presentation of the study is as follows:



Figre 3.1: Graphical Presentation of Research Framework

CHAPTER FOUR

Data analysis, Results and Discussion

4.1.Data Analysis, Results and Discussion

This unit contains the analysis of the data that was gathered through the use of a questionnaire.**4.2.General Demographic Data presentation and Discussion**

As shown in Appendix XIV, the total number of questionnaires circulated was 140, and the number of questionnaires that were completely filled and returned was 115, resulting in an 82 percent successful response rate for this study. (Babbie, 2004) argued that, a response rate of more than 50% is acceptable, 60% is good, 70% is outstanding, and anything beyond 80% is excellent. As a result, the study's response rate of 82 percent was excellentstudy. This component necessitated the collection of data on the overall profile of the respondents. The age, highest degree of education, and job experience of the respondents in the company where all covered in this section. According to the findings, most respondents were between the ages of 31 and 41, followed by 28 perecent between the ages of 41 and 50. Furthermore, 24 percent of those surveyed were under the age of 30, whyle only 15% wre beyond the age of 51. The company is considered as a potential solution to ethiopian's expanding youth employment challenges; as a result, the company is important to youth as a source of employment.The study also aimed to determine the respondent's highest level of education within the company. Appendix XIV summarizes the findings of the study. According to the findings of the study, the majority of the respondents (48%) had a diploma level of education, with another 28% having an undergraduate level of education. The study's respondents had a certificate level of education, which accounted for 19% of the total. Finally, 5% of respondents reported that they had completed a postgraduate degree. This indicates that the majority of the survey respondents in the company are educated, and so comprehended the items in the questionnaire and provided credible responses for analysis.Appendix XIV shows that the majority of the respondents, 44 percent, had more than 10 years of work experience in the organization, while 26 percent reported that they had 6 to 10 years of work experience. Those with 1 to 5 years of experience accounted for 18% of the total, while those with less than one year of experience in the organization accounted for 11%. The results show that the majority of the respondents had worked in the printing industry for more than 5 years and so had sufficient experience to respond to the questionnaire.

4.3. Descriptive Findings and Analysis of Maintenance and Production Performance

On each of the criteria, the respondents were asked to rate their level of agreement with statements. A five-point Likart scale was employed, with 5 representing strongly agree, 4 representing agree, 3 representing undecided, 2 representing disagree, and 1 representing strongly disagree. This section shows the descriptive statistics for each respondent's percentage. The secretion was presented in accordance with the goal.

Table 4.1:Data Summary (Own)

	Description	**1**	**2**	**3**	**4**	**5**
Challenges of machinary maintenance	The distance of the machines from the stock room does not have important role in manipulating the machine stoppage.	12	51	30	13	9
	The existing tools are old and doesn't help to repair the machine during maintenance.	29	37	42	7	0
	Primacies is not given to maintenance plan and the primacy is given to production without ensuring good maintenance practice.	3	9	23	49	31
	The mechanics are lacking attention to particulars and they are only concentrating towards a rapid repair work towards equipment failure.	10	7	27	53	18
	The reporting order is suitable to carry about the maintenance and production improvement.	7	22	33	47	6
	The administration doesn't give sufficient attention to training of manpower to improve the mechanic abilities.	6	8	38	52	11
	The mechanics refer documents and manuals of manufacturers of the machines while doing maintenance activities.	3	15	37	53	7
Training plans related to maintenance	The company have well trained and expriancedtechniciance.	3	56	2	30	24
	Scheduled training programs are given on maintenance technician.	27	33	23	17	15
	Maintenance technicians are well skilled.	7	37	15	53	3
	Production workers get training to perform their task correctly.	37	43	23	8	4
	You are familiar with the installed machine of the company.	3	15	35	60	2
	You think training is significant for effective maintenance.	1	7	17	55	35
	The company have low cost and accessible training facilities.	12	29	13	42	14

	Description	1	2	3	4	5
Equipment optimaization of the company	I use information gathered from the equipmen's to identify and prioritize maintenance actions.	13	57	35	7	3
	I monitor equipment availblity through operating time, scheduled downtime, and unscheduled downtime.	29	45	32	50	4
	I compare the total units produced aginest the defective units produced by equipment on an ongoing basis.	3	48	22	33	9
	I fully apply effort to improve equipment capacity, uptime, and production cycle time.	5	4	6	56	44
Maintenance planinig and scheduling	You planned shutdowns maintenance for major repairs in advance.	4	54	47	8	3
	The maintenance task is accomplished, the techniciance that accomplished the task reports the real working time, used material, and stoppage.	3	17	25	57	13
	You have appropriate spare parts for maintenance.	12	63	27	7	6
	The entire quantity of work orders have been delayed due to poor or incomplete plans.	22	27	43	18	5
	You set priorities for maintenance job tasks.	3	7	25	45	35
	The equipment's are maintened within a short time when the equipment's failed.	13	43	17	37	5
Planned preventive maintenance	The maintenance department supports machine operators perform their own preventive maintenance.	6	19	34	46	10
	There is an isolated shift, or part of a shift, kept each day for maintenance activities.	8	12	29	51	15
	Cleaning, oiling, tightening and inspection of equipment are carried out regularly.	3	11	31	37	33
	There is a devaoted time period where the equipment is shutdown for maintenance.	15	43	24	18	15
	Daily maintenance applies help achieve good quality products for our equipment and schedule contract.	2	6	29	47	31
	There is adevoted time period where the production and maintenance members meet to plan for maintenance.	17	42	23	24	9

	Descripition	1	2	3	4	5
Production performance	Our company has improved the ability to produce above distinguished capacity on some equipment's.	15	32	48	11	9
	Our company has reduced the costs involved in printing products.	13	29	41	27	10
	Our company has improved the ratio of finshed products to raw materials.	3	55	31	24	2
	Our company has reduced the number of products returned due to quality defects.	7	15	33	47	13
	Our company has reduced the amount of scrap generated by our equipment's.	25	38	42	6	4
	Machine stoppage reduces intended or planned production capacity.	10	15	20	43	27
	Total production time affected by the amount of machine downtime.	4	9	23	37	42

4.3.1 Challenges Of Machinery Maintenance

The participants were asked to rate extent to which they agreed with the statements about the challenges of machinery maintenance in the company. The results in Table 4.1 above shown that a total of 51 respondents disagree with the statement the distance of the machines from the stock room does not have important role in manipulating the machine stoppage. The majorityof the respondents disagreed with the statement that the existing tools are old and doesn't help to repair the machine during maintenance. The majority of the respondents agreed that primacis is not given to maintenance plan and the primacy is given to production without ensuring good maintenance practice. The majority of the respondents agreed that the mechanics are lacking attention to particulars and they are only concentrating towards a rapid repair work towards equipment failure.The study further shown that the majority 47 respondents agreed that the reporting order is suitable to carry out the maintenance and production improvement. the majority of the respondents i.e 52 agreed that the administration doesn't give sufficient attention to training of manpower to improve the mechanic abilities. Finally,the findings revealed that the majority 53 respondents agreed that the mechanics refer documents and manuals of manufacturers of the machines while doing maintenance activities.It may be inferred that the lack of good maintenance methods has a direct impact on the achievement of production objectives, inadequate machinery maintenance will result in longer downtime, greater maintenance cost, lower product quality, and lower manufacturing productivity.

4.3.2 Training Plans Related To Maintenance.

The participants were asked to rate the extent to which they agreed with the statements concerning training plans related to maintenance in the company. The outcomes in Table 4.1aboveshown that a total of 56respondents disagreed that the company has well-trained and experienced technician. The study outcomes also discovered that the majority of respondents disagreed that scheduled training programs are given on maintenance.Maintenance technicians are welltraineda total of 53respondents agreed. Production workersnot get training to performthem their tasks correctlybecause the majority of the respondents disareed with the statement.The majority of the respondents agreed that you think training issignificant for efficient maintenance. Finally, the findings showed that the majority of the respondent agreed that the company has low cost and accessible training facilities. It can be concluded that, despite having readily available training facilities, the company fails to provide proper training to technicians and machine operators. As a result, the company fails to meet its production goals, resulting in increased machine downtime, higher maintenance costs, lower product quality, and lower production output.

4.3.3 Equipment Optimization of the Company.

The participantswere asked to rate the extent to which they agreed with the statements concerning equipment optimization in the company. The outcomes in Table 4.1 above indicated that a total of 57respondents disagreed that I use information gathered from the equipment's to identify and prioritize maintenance actions.The study outcomes also discovered that the majority of the respondents disagreed that I monitor equipment availability through operating time. I compare the total units produced against the defective units produced by equipment on an ongoing basis a total of 48 respondents disagreed with the idea. A total of 56 respondents agreed that I fully apply effort to improve equipment capacity, uptime, and production cycle timeIn general, Poor equipment management leads to lower levels of performance, reliability, and significant production process stoppages, as well as higher repair costs.

4.3.4 Maintenance Planning and Scheduling.

The respondents were asked to rate the extent to which they agreed and disagreed with the ideamaintenance planning and schedulingin the company. The outcomes in Table 4.1above indicated that a total of 54 respondents disagreed with the idea you planned shutdown maintenance for major repairs in advance.The study outcomes also discovered that the majority of the respondents agreed that the maintenance task is accomplished, the techniciance that accomplished the task reports the real working time, used material, and stoppage. You have appropriate spare parts for maintenancea total of 63 respondents disagreed with the idea.The majority of the respondents agreed that the entire quantity of work orders have been delayed due to poor or incomplete plans. Majority of the respondent agreed that You set priorities for maintenance job tasks. The survey shown that a total of 46 respondents agree that equipments are maintened within a short time when the equipment's failed.

4.3.5 Planned Preventive Maintenance.

The respondents were asked to rate the extent to which they agreed and disagreed with the idea maintenance planning and schedulingin the company. The outcomes in Table 4.1above indicated that a total of 46respondents agreed that the maintenance department supports machine operators perform their own preventive maintenance.There is an isolated shift, or part of a shift, kept each day for maintenance activities a total of 52 respondents agreed with the idea.A total of 37 reapondentsagreed that cleaning, oiling, tightening and inspection of equipment are carried out regularly.There is a devoted time period where the equipment is shut down for maintenance a total of 43 respondents disagreed with the idea.Daily maintenance applies to achieve good quality products from our equipment and schedule contractamajority of the respondents agreed with the idea. The outcome also showed that there is a devoted time period where the production and maintenance members meet to plan for maintenancea total of 42 respondents disagreed with the idea.

4.3.6 Production Performance.

The respondents were asked to rate the extent to which they agreed and disagreed with the idea maintenance planning and schedulingin the company. The outcomes in Table 4.1above indicated that a total of 48respondents disagreed that our company has improved the ability to produce above designed capacity on some equipment's.Our company has reduced the costs involved in printing products the majority of the respondents disagreedwith the idea.The majority of the respondents disagreed that our company has improved the ratio of finished products to raw materials.Our company has reduced the number of products returned due to quality defectsa total of 47 respondents agreed with the idea. A total of 42 respondents undecided with the idea Our company has reduced the amount of scrap generated by our equipment's. Machine stoppage reduces intended or planned production capacitya total of 43respondents agreedwith the idea.The research finding lastly revealed that the majority of the respondent strongly agreed that total production time is affected by the amount of machine downtime. Productivity is an importantcomponent in any manufacturing company thorough to recognizehigher manufacturing performance which is a competitive advantage.

4.4.Machine Downtime Analysis and Discussion.

Thestoppage timeinvestigation of the equipment located in the enterprise'sfour(4)production(printing) divisions, i.e, offset printing, web-offset printing, letterpress, and security printing divisions, is done utilizing document records.

i. Offset printing division

The total downtime recorded for each machines in offset printing division

Table 4.2:Planned production time and total downtime of machines in offset printing section(company report)

Machine Name	Planned production time	Total down time	Net operating time	Productive time (%)	Non-Productive time (%)
Mo-13	3,192	1,869.46	1,322.54	41.4	58.6
Speed Master-74-1	1,620	1,354.74	265.26	16.4	85.6
Speed Master-74-2	3,192	2,064.36	1,127.64	35.3	64.7
Speed Master -102-1	1,620	1,410.38	209.62	13	87
Sakurai 266-1	3,192	2,190.48	1,001.52	31.37	68.63
Sakurai 480	3,192	2,472.38	719.62	23	77
GTO-52	3,192	841.08	2,350.92	73.65	26.35
GTO-46	3,192	363.1	2,828.90	88.62	11.38
GTO new	3,192	1,953.14	1,238.86	38.8	61.2

In the above table 4.2and figure 4.1belowshows that the proportion of production time and non-production time machines in the year (2018/2019) in the offset printing section 88.62 percent and 87 percent, respectively, are the most productive and non-productive values. 13 percent and 11.38 percent, respectively, are the lowest productive and non-productive values. The results show that there is a high incidence of downtime in the division due to unintentional machine failures, which causes the division's planned production time to be disrupted. This extended downtime caused by equipmentstopageobviously indicates that the enterprise maintenance activity is low.Therefore in the figure below shows that the percentage of the productive and non-productive time in the offset printing section.

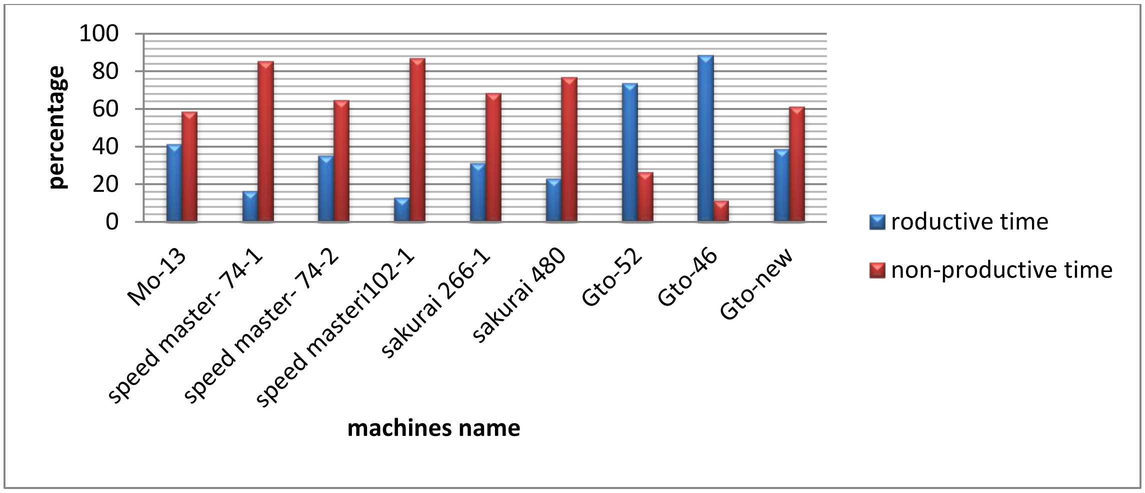


Figure 4.1: productive and non-productive percentage of machines in offset printing section

ii. Web offset printing division

In web-offset production division the total stoppage (downtime) recorded in every machines

Table4.3: Planned production time and total downtime of machines in web-offset printing section (company report)

Machine Name	Planned production time	Total down time	Net operating time	Productive time (%)	Non-Productive time (%)
Solna 01	3,192	3,155.06	36.94	1	99
Solna 02	3,192	2,766.72	425.28	13	87
Prima 578	3,192	3,011.78	180.22	6	94
Prima 546	3,192	2,923.64	268.36	8	92

In the above Table 4.3and figure 4.2 belowshows that the greatest productive and non-productive values in the year (2018/2018) are respectively 13 percent and 99 percent. The lowest productive and non-productive values are respectively 1% and 87 percent. The result indicates that there is a significant incidence of downtime in the division due to unplanned machine failures, which causes the division's planned production time to be disrupted. Because of the extended downtime caused by machine failures, the company's maintenance performance is very low.

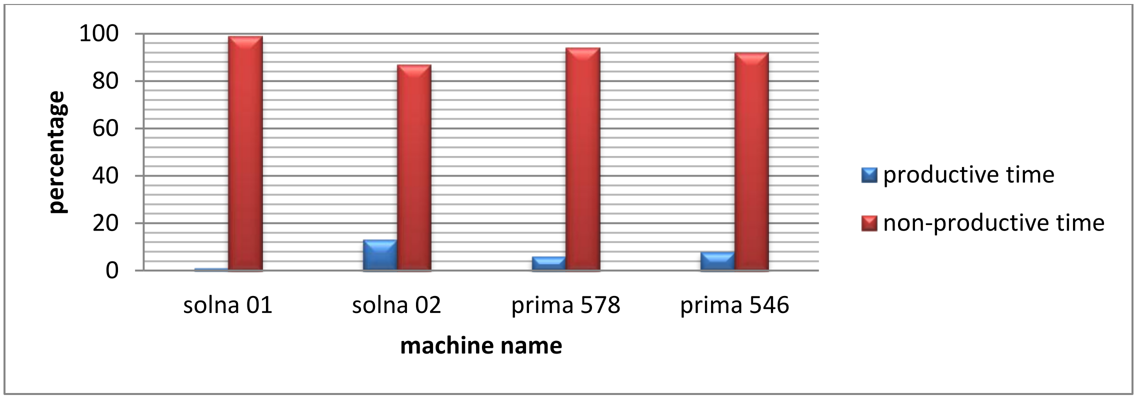


Figure 4.2: productive and non-productive percentage of machine in web-offset printing section.

iii. Security press printing division

Table4.4: Planned production time and total downtime of machines in security printing division (company report)

Machine Name	Planned production time	Total down time	Net operating time	Productive time (%)	Non-Productive time (%)
Sakurai 2	3,192	1987.16	1,204.84	38	62
Sakurai 266.2	3,192	1995.42	1,196.58	37	63
SM 102.2	3,192	2,087.96	1,104.04	35	65
Ronald	3,192	1,797	1,395.20	44	56
Cylinder 08	3,192	218.14	2,973.86	93	7
Cylinder 15	3,192	1,323.06	1,868.94	59	41
Cylinder 16	3,192	1,207.20	1,984.80	62	38
Cylinder 28	3,192	1,541.70	1,650.30	52	48
Platen 02	3,192	1,063.62	2,128.38	67	33
Platen 13	3,192	516.14	2,675.86	84	26
Platen 14	3,192	1,258.16	1,933.84	61	39
Platen 21	3,192	218.14	2,973.86	93	7
Platen 26	3,192	818.26	2,373.74	74	26

In the above Table 4.4and figure 4.3 belowshows that the greatest productive and non-productive values in the year (2018/2019) are respectively 93 percent and 65 percent. 35 percent and 7%, respectively, are the lowest productive and non-productive values. The result indicates that there is a significant incidence of downtime in the division due to unplanned machine failures, which causes the division's planned production time to be disrupted. Because of the lengthy downtime caused by machine failures, the company's maintenance performance is very poor.

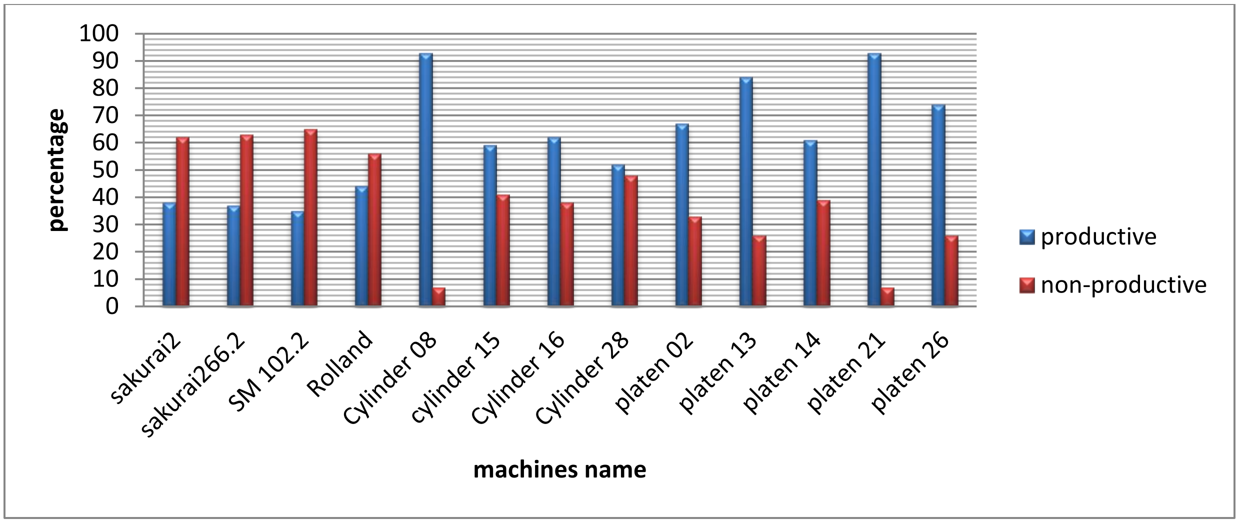


Figure 4.3:productive and non-productive percentage of machines in security printing section.

iv. Letter press printing division

The (stoppage) downtime recorded ineverymachines in latter press printing division

Table4.5: Planned production time and total downtime of machines in latter press printing section (company report)

Machine Name	Planned production time	Total down time	Net operating time	Productive time (%)	Non-Productive time (%)
Gto 046	3,192	1,458.72	1,733.28	54	46
Gto 026	3,192	2,966.86	225.14	7	93
Cylinder 30	3,192	1,101.244	2,090.76	66	34
Cylinder 9	3,192	1,085.40	2,106.60	66	34
Platen 22	3,192	1,215.84	1,976.16	62	38
Platen 24	3,192	808.46	2,383.54	75	25

In the above Table 4.5and figure 4.4 belowshows that the greatest productive and non-productive values in the year (2018/2019) are respectively 75% and 93 percent. The lowest and highest productive and non-productive values are 7% and 25%, respectively. The result indicates that there is a significant incidence of downtime in the division due to unplanned machine failures, which causes the division's planned production time to be disrupted. Because of the lengthy downtime caused by machine failures, the company's maintenance performance is very poor.

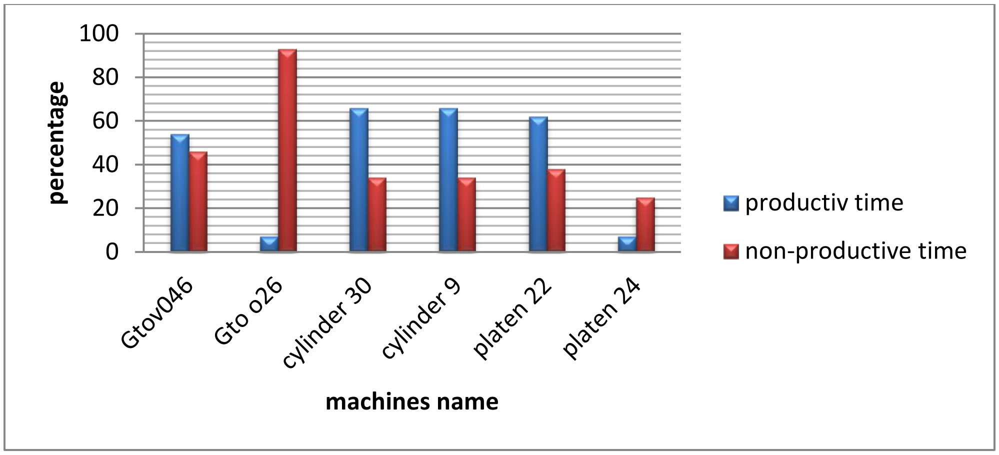


Figure 4.4:productive and non-productive percentages of machines in latter press printing section.

4.4.1Machine Performance Analysis Using OEE and Discussion.

Secondary data is gathered and analyzed using OEE to investigate the current state of the company in terms of maintenance and equipment performance.

OEE is regarded as a critical metric for assessing equipment performance. The technique distinguishes six major loss kinds as well as three key performance indicators: availability, performance rate, and quality rate, which are combined into a single metric. By identifying those performance opportunities that will have the greatest influence on the bottom line, the OEE can be utilized to help focus on increasing the performance of machines and related processes. The OEE metric can be used to measure and improve enhancements in changeovers, quality, machine reliability, working during breaks, and more. The proportion time that equipment would have to run at maximum speed in order to achieve the actual output of that tool or machine is known as OEE. The overall equipment effectiveness is measured for machines used in the company's printing business, which includes offset printing, web offset printing, security printing, and letter press printing.

Equipment/machine performance is expressed in terms of overall equipment effectiveness.

- Overall Equipment Effectiveness(OEE) is calculated in the following way;

Overall Equipment Effectiveness(OEE) = Availability*Performance Rate *Quality Rate

4.4.2MachinePerformance Based On Working Hours.

There are 32 major machines in the Berhanena Selam printing enterprise's four printing production lines: offset printing, web-offset printing, security printing, and letterpress printing. Each machine is supposed to produce five and a half hours per shift. According to company policy, setup time is set at half an hour and make ready time is set at one hour. Every day, all of the machines perform two shifts. Machine downtime, speed loss, and machine availability data, as well as quality defect data, were gathered and analyzed for the years 2018/219, 2019/2020, and 2020/2021. The data analysis was done with Microsoft Excel and the results are presented in tablesas shown in AppendixI-VI and graphs as shown in figur4.5 to 4.7. The summary of the available, actual working hours, downtimes as well as quality defect rate data which are registered in twelve monthsof two years and seven months of one year data is summarized and presented in different tables indicated in Appendix I-VI.

4.4.3 Machines Availablity Based On Impression

Appendix-I shows machine availability based on expected and actual working hours in the year 2018/2019 of twelve (12) months the average availability of the machines based on the working hours was 60.4% from this 39.6% of the working hours was lost due to different maintenance problems which the major cause for the machine downs was improper maintenance. Appendix-II shows the performance of the printing machine based on their expected impression and the actual impression in the year 2018/2019 of twelve (12) monthsthe average performance of the machines in the four printing production processes has 65.0%, this indicates due to different problems there is 35% of speed loss recorded in the given time period,Appendix-III shows machine availability based on expected and actual working hours in the year 2019/2020 of twelve (12) months the average availability of the machines based on the working hours was 57% from this 43% of the working hours was lost due to different maintenance problems also which the major cause for the machine downs was also improper maintenance,Appendix-IV shows the performance of the printing machine based on their expected impression and the actual impression in the year 2019/2020 of twelve (12) months the average performance of the machines in the four printing production processes has 61.0%, this indicates due to different problems there is 39% of speed loss recorded in the given time period,Appendix-V shows machine availability based on expected and actual working hours in the year of 2020/2021 seven (7) months the average availability of the machines based on the working hours was 54%. From this 46% of the working hours was lost due to different maintenance problems also which the major cause for the machine downs was improper maintenance andAppendix-VI shows the performance of the printing machine based on their expected impression and the actual impression in the year 2020/2021 of seven (7) months the average performance of the machines in the four printing production processes has 57.0%, this indicates due to different maintenance problems there is 43% of speed loss recorded in the given time period.

According to the case company three years report as shown Appendixes I-VIthe availability and performance of the machines in four printing production sections are reduced from year to year the main cause for machine working hours and speed losses is inappropriate maintenance. The research considers both machine availability and the performance measurements based on the average results of all machines.

4.4.4 Rejects and Rework

Any organization's key skills include quality. In this competitive market, delivering a high-quality product is more important than anything else. BSPE is unable to satisfy its quality standards due to a lack of effective and scientific process control procedures. There is a quality risk in each of the four printing sections. Based on the year2018/2019 of 12 months of four printing production performance reports, 448,016,200 different printed product quantities were registered and of which 7,193,697 products were defective. Therefore the defect rate was 1.66% and the product quality level was 98.34% according to the data registered as shown in appendix-VII,in the year2019/2020 of 12 months of four printing production performance reports,462,950,073different printed product quantities were registered and of which 7,943,042products were defective. Therefore the defect rate was 1.72% and the product quality level was 98.28% according to the data registered in appendix-VIIIandin the year2020/2021 of seven (7) months of four printing production performance reports,280,461,547different printed product quantities were registered and of which 5,097,411products were defective.

Therefore the defect rate was 1.82% and the product quality level was 98.18% according to the data registered in Appendix-IX,since the result shows that in all years all printing production process products which was at high risk the expected quality level is 99.99%. So the result of the data analysis indicates that the company produces less quality products due to poor maintenance.

4.4.5 Printing Machines OEE Analysis

As in any manufacturing industries the three main categories in printing machine's related losses are downtime loss, speed loss, and defect or quality loss are the main factors for deterring the overall equipment effectiveness. Therefore the researcher calculated the Overall Equipment Effectiveness (OEE) by combining three factors that reflect these losses.

$$\text{OEE} = \text{Availability} \times \text{Performance Rate} \times \text{Quality Rate}$$

A) Availability(A)

The amount of time a printing machine is available for production is measured by its availability; as a result, it is a measure of how well the machine is performing and how much downtime there is.In this study machine availability analysis was performed by comparing the actual operating time to the planned operating time for the printing machine based on three years data this are shown appendix-I, III and V.

Availability is expressed as:

$$\text{Availability} = \frac{\text{Actual Operating Time}}{Planned\ Operating\ Time} \times 100$$

B) Performance Rate (Pr)

The performance rate compares the real production output to the theoretical output by measuring the printing transform input to output. In this study machine performance analysis was performed by comparing the planned machine speeds (planned impression) and the actual machine speeds (actual impression) for the printing machine based on their impression (speed) in three years are shownAppendix-II, IV and VI.

Performance can be calculated as follows;

$$\text{Performance Rate} = \frac{\text{Acutual Avarage Production}}{\text{Standard Production}} \times 100$$

C) Quality Rate(Qr)

The percentage of good parts in total items produced is known as the quality rate. When the line is producing, yet there are quality losses owing to in-process production and warm-up rejects, this is referred to as a quality loss.From thethree yearsdata of 2018/2019, 2019/2020 and 2020/2021 shown in Appendix VII, VIII and IX the highest percentage of quality 99.1%isrecorded in the month of Novemberin the year 2018/219 and the lowest percentage of quality were in July, at95.4% in the year 2019/2020 as shown in Appendix IX quality takes into consideration quality loss, which accounts for produced pieces that do not meet quality standards, including those defective products that require rework, called wastage. Quality can be calculated as follows;

$$\text{Quality Rate} = \frac{\text{No.of Products Processed} - \text{No.of Products rejected}}{\text{No.of products processed}} \times 100$$

D) Overall Equipment Effectiveness(OEE) Analysis

OEE measurement is made up of three factors: availability, performance, and quality. Each one is expressed as a percentage and accounts for a different kind of waste in the print in the printing production process discussed before. Overall Equipment Effectiveness can be calculated as;

OEE = availability *performance*quality

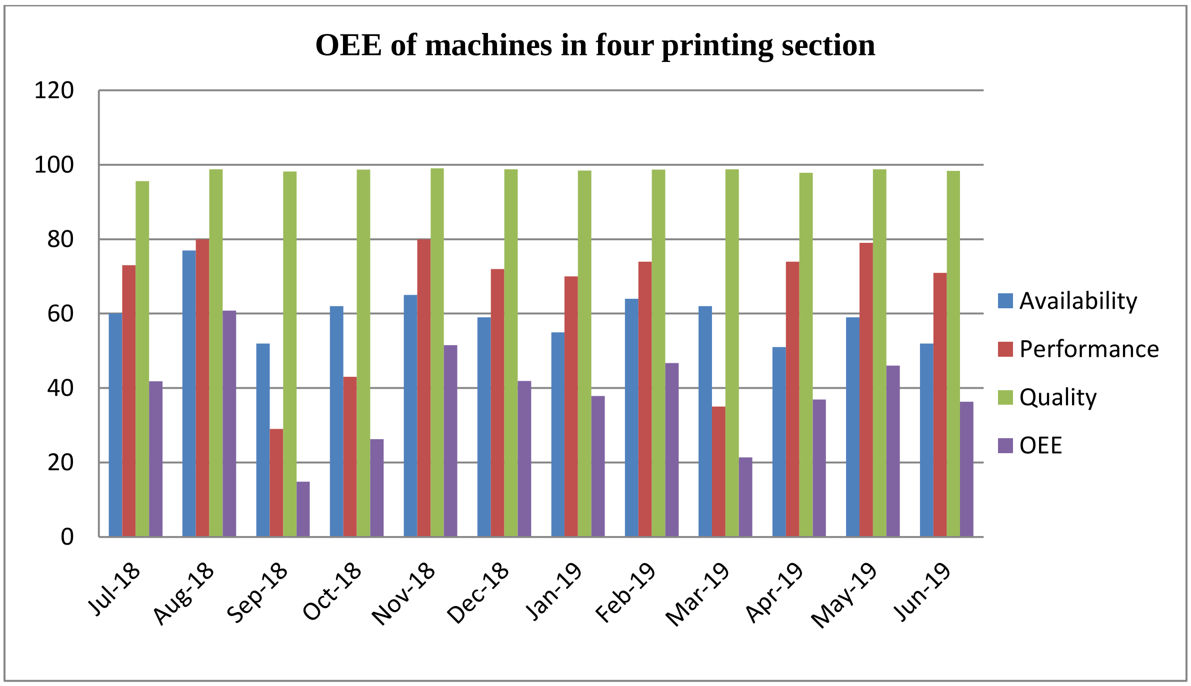


Figure 4.5: OEE of machines in four printing sections 2018/2019 twelve months

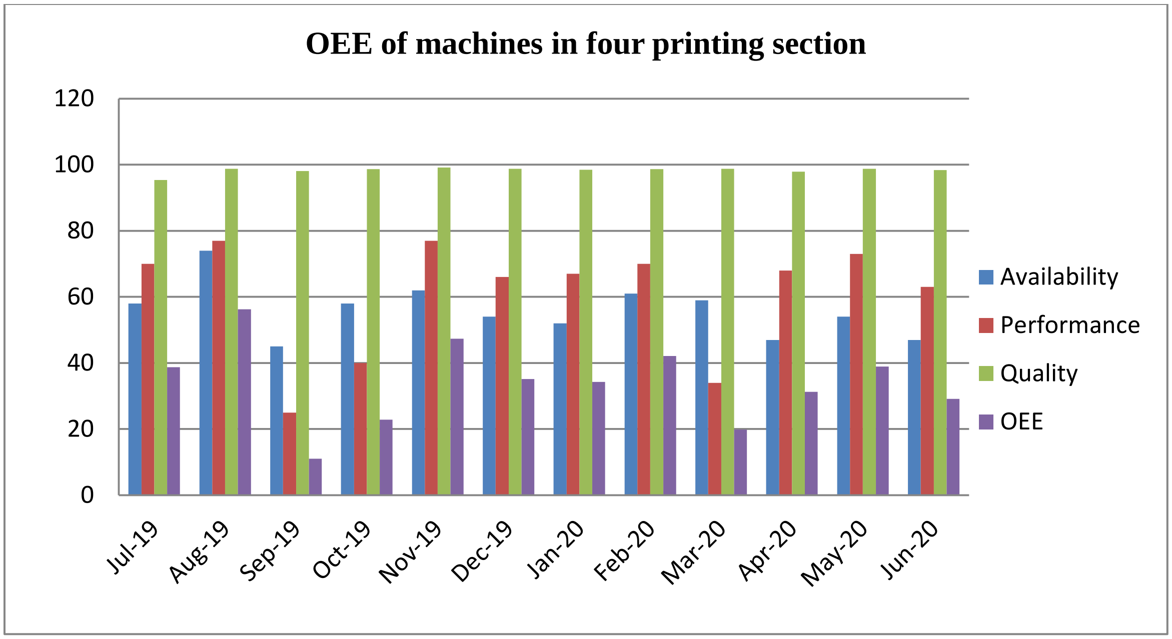


Figure 4.6: OEE of machines in four printing sections 2019/2020 twelve months

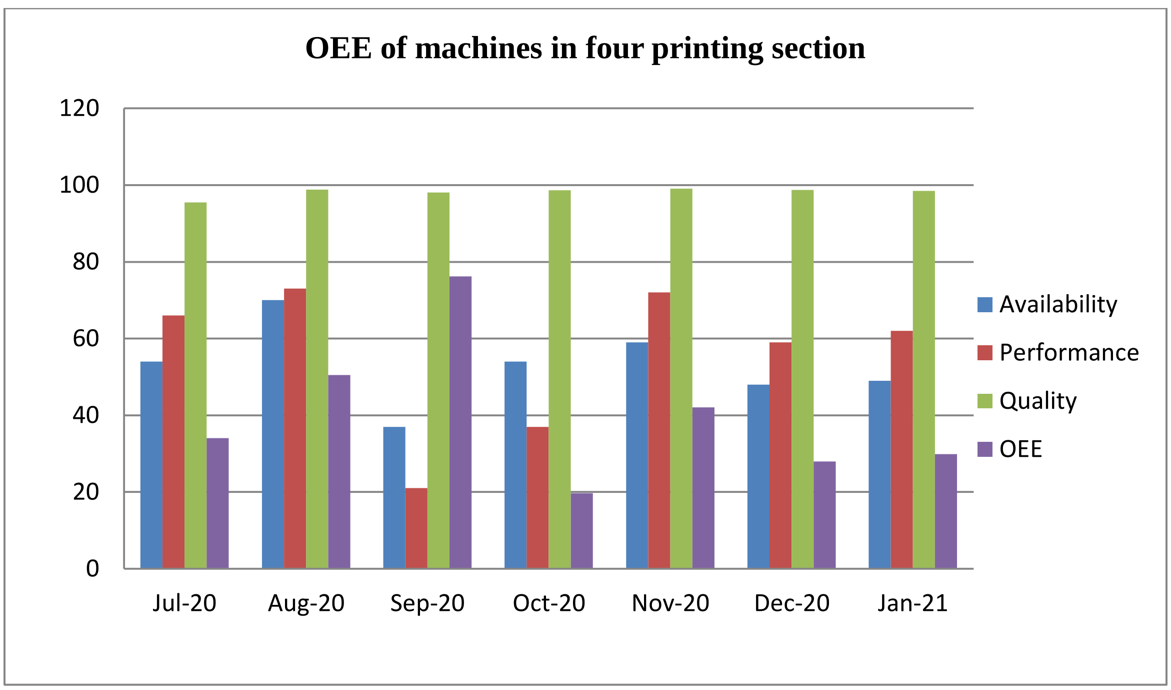


Figure 4.7: OEE of machines in four printing sections 2020/2021 seven months

The OEE of the company in the year 2018/2019, 2019/2020 and 2020/2021 is 38.56%, 34.17% and 30.22% respectively which means that the printing machines in the company are running effectively only 38.56, 34.17 and 30.22% of its time in each year. The percentage of OEE for printing machines of the company is shown in Figure 4.5, 4.6 and 4.7 in each year.

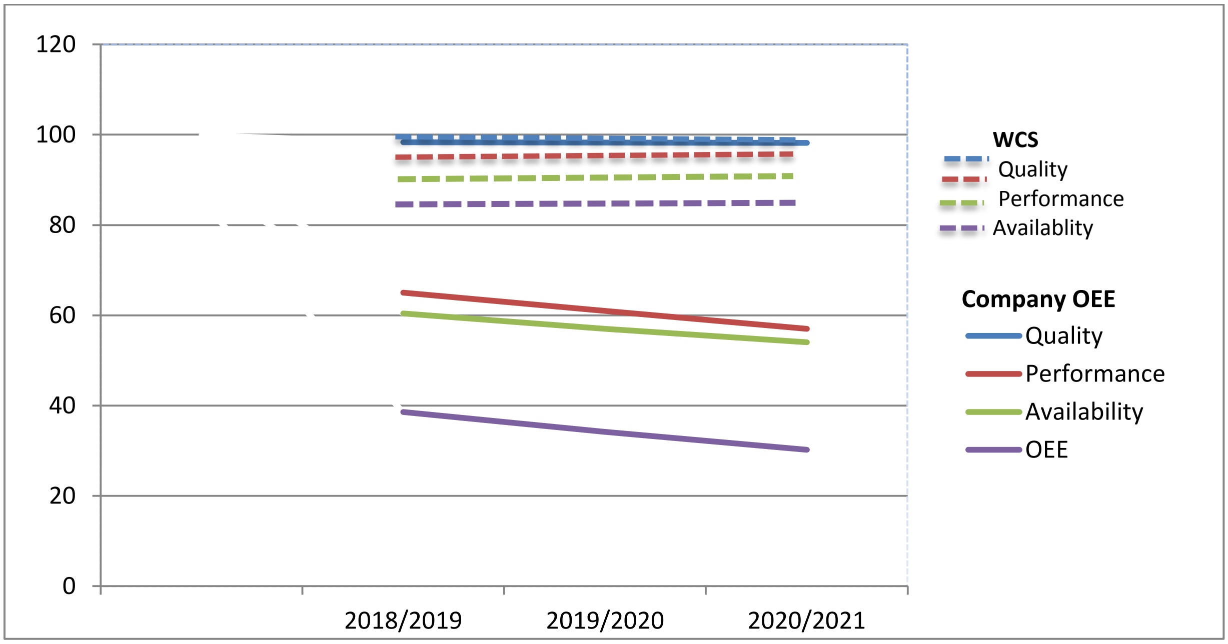


Figure 4.8: Comparison between world classes OEE and company

4.4.6 Summary of OEE.

The OEE results show that the company is 46.44 percent, 50.83 percent, and 54.78 percent below the world-class OEE standard in each of the three years. According to the report, 95 percent of machine maintenance operations are performed after a machine breaks down due to a lack of a good maintenance strategy. Machines performed poorly in terms of speed and availability as a result of these conditions, resulting in a fall in Overall Equipment Effectiveness.

4.5Root Cause Findings

For finding the root cause of reduced machine availability, performance, and printing defects a focused group discussion, consisting of 12 workers from selected production managers, maintenance directors, and even selected production and maintenance workers, and by directly observing the company's production area were performed. The selected department's management team worked together brilliantly.

4.5.1.Cause and Effect Diagram

Cause and effect analysis is a technique for examining and visualizing a process by displaying the major cause and sub-causes that contribute to the result (Wilson.P, 1993). Figures 4.9 and 4.10below shows the cause and effect diagrams for reduced machine performance and reduced machine availablityof the company.

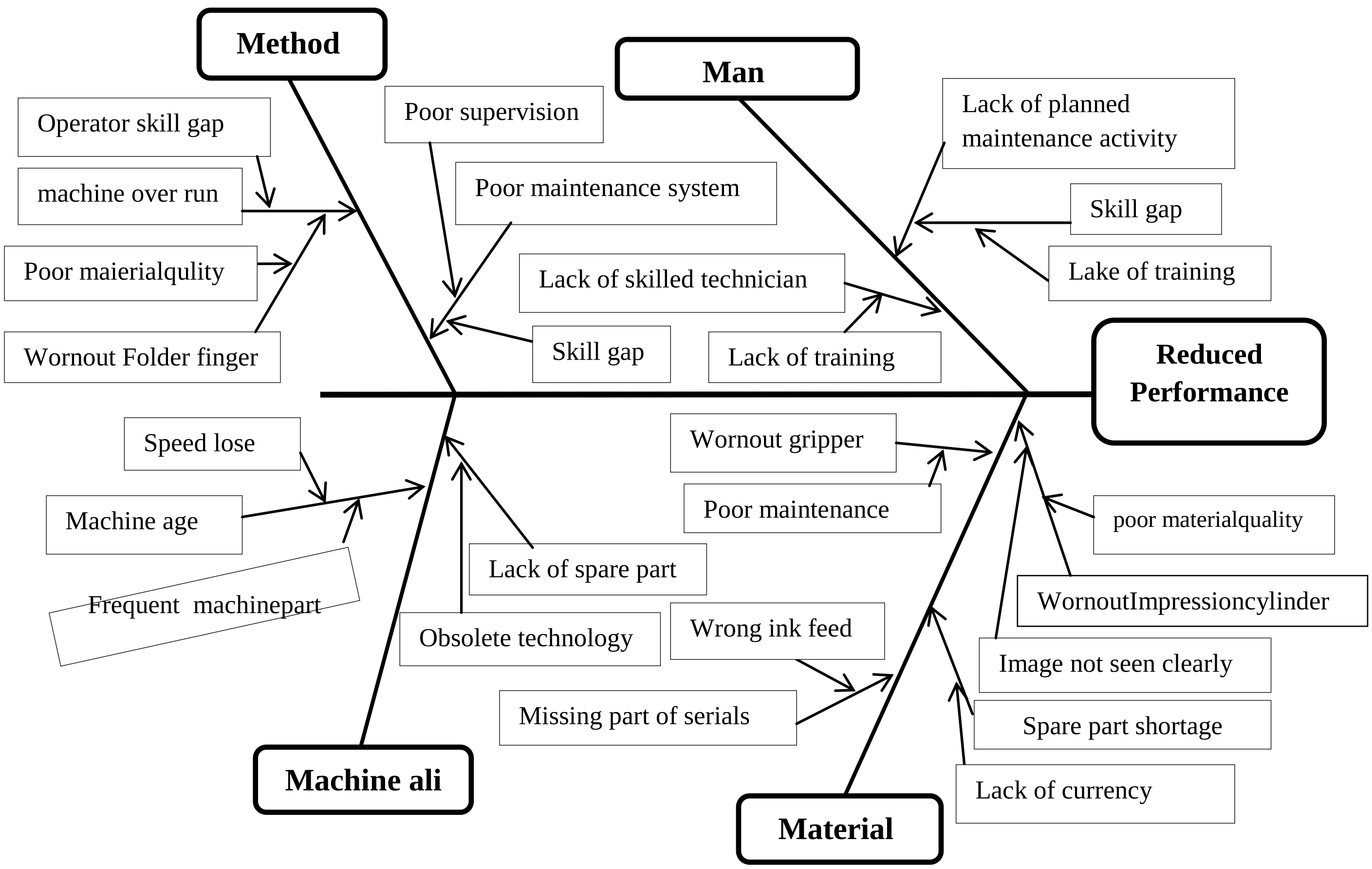


Figure 4.9: Cause and effect diagram for reduced machine performance

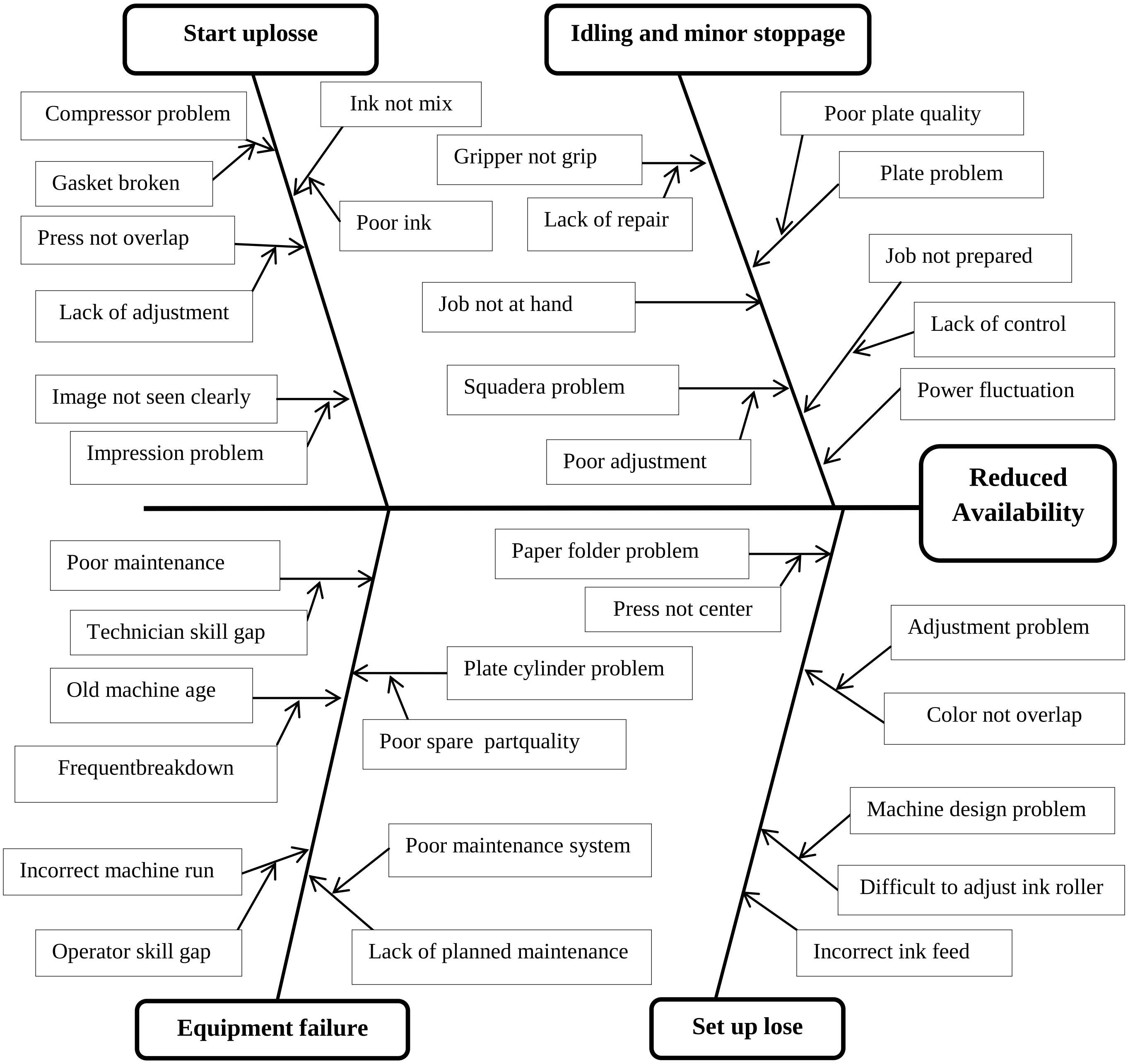


Figure.4.10: Cause and effect diagram for reduced machine availability

The cause and effect diagram shows that if the company eliminates/minimize the identified potential causes, machine availability and performance will be increased. Corrective actions to eradicate the underlying causes were discussed and summarized in the table below based on the identified root causes of the primary problems in the cause and effect diagram.

Table 4.6: Main root Causes and corrective action to eliminate/reduced the root causes.

No	Main Root Cause	Corrective action
1	Poor maintenance system	Improve maintenance system to solve maintenance related problems.
2	Skill gap	Give necessary training for maintenance technicians and production workers.
3	Old machines	Properly mantain old machines in addition to this Buy new technological machine to solve speed lose proble of the machine.
4	Poor spare part quality	Buy good quality spare parts from local and forign markets.
5	poor planned maintenance	Give attention to planned maintenance to increase availability and performance of the machine.
6	Lack of spare parts	Buy new spare parts and do modification within company workshop and outside company workshop.
7	Poor breakdown maintenance	increase systematic and good maintenance of themachine to increase machine life.
8	Poor maintenance administration	Give training to maintenance supervisors and maintenance staff

4.6. Productivity and Profitability Analysis

Improvements in maintenance aim to reduce operating costs, improve product quality and improve productivity. Therefore, the cost effectiveness of each improvement action could be examined by assessing the relevant cost parametrsbefor and after improvments. Profitability is the result of instruction of controllable and uncontrollable factors. Among uncontrollable factors are the economic and poltical environment, market growth or decline, inflation, etc. Those uncontrollable factors could impose significant positive or negative impact on profitability (Loggerenberg, 1981). The impact should be measured in a way that allows knowing if the chang in profit is due to the changes in the uncontrollable factors or the controllable factors. During the late 1970s and early 1980s the American productivity and quality center defined profitability as the product of productivity and price recovery. The productivity could be define as the ratio of out put quantity produced to the sum of one or all input factors required to produce the output quantity such as manpower, material, and energy. The price recovery measurs the ratio of price of the output products to the allocated cost of the consumed inputs unit, as shown in the following equestion(Sumanth, 1998).

Profitability = productivity*price recovery = output/input*price/cost…………..eq.(1)

The change in the index value point out wha are the causes of change in profitability. The price recovery index represents the effet of the uncontrollable factors, whil the productivity index represents the effect of the internal controllable factors, i.e. machine utilization (Sink, 1989). In this study focused on machine productivity, assume that Q1 is the quantity of quality product produced when using a certain maintenance policy, which resulted in the total manufacturing cost TC1. When the company implement effective maintenance policy that requires a new investement of (I), this could result in increasing the quantity produced to Q2. Therefore, company’s profit in relation to productivity, or the effect of using more effective maintenance policy on the productivity can be calculated by using the following equation.

Profit befor improvement F1 = Q1(Price-TC1)…………………………………………........eq.(2)

Profit after improvement F2 = Q2(Price-TC2)……………………………………………..eq.(3)

Net profit = F2-F1 …………………………………………………………………….eq.(4)

If the net profit is greater than the cost improvement, i.e, required for achieving the increase in output, then the investment is cost effective. In the following explain using empirical data how productivity and profitability improve by using effective maintenance system in the company.

From the company repors it was found that the actual annual quantity produced during the study period, i.e. 2018-2020, was Q1 = 440,822,503M² and the total production 450,152,321M². The average selling price was about 1.9 Birr/M². The avargetotal production cost, i.e, TC1 at Q1 was about 1.64 Birr/M². The average quantity of production lost because of unavilablity due to all types of machine stoppage were 7,193,697M². In ideal case, when the company use the proposed maintenance system would eliminate all stoppages, the new quantity produced would be 448,016,200M² and TC2 would become 1.60 Birr/M². Based on the above mentioned data, the productivity index calculated accourding to Eq.(1) at point Q1 is about 1.183, also, the value of productivity index would be improved to about 1.213 at Q2 . This means that the productivity index of one printing machine could be improved by an increment of 0.03 when the company used the proposed maintenance system. Thus, the ideal net impact on the company profit without the cost of investment can be calculated using Eq.(2)-(4) as:

$$F2 = 440,822,503(1.941.64) = 132,246,750$$

$$F1 = 448,016,200(1.941.60) = 152,325,508$$

$$F2\text{-}F1 = 20,078,758 \text{ Birr}$$

This means that ideally, at least 2.07 million Birr per year, i.e, about 13.2% of the machine yearly maintenance budget, could be gaind as a result of productivity improvement of one printing machine,when the proposed maintenance system has been used. This value will increase accourding to how the maintenance actions are linked to the cause of other elements of the overall equipment effectiveness.

4.7. Discussions of Results

The findings of the study in relative to each of the specific objectives were compared with the literature review. The results of the study are discussed under here below.

From the investigation questionnaire outcome the maintenance problems summary is as follows, for the questions given in challenges of machinery maintenance the majority of the respondent gives negative response that the distance of the machines from the stock room does not have important role in manipulating the machine stoppage, their existing tools are old and doesn't help to repair the machine during maintenance, Priorities is not given to maintenance plan and the primacy is given to production without ensuring good maintenance practice, but they have a positive response about the mechanics are lacking attention to particulars and they are only concentrating towards a rapid repair work towards equipment failure, the mechanics refer documents and manuals of manufacturers of the machines while doing maintenance activities, in conclusion the absence of good maintenance practices has a direct effect on production objective attainment. Inappropriate machinery maintenance will lead to a prolonged downtime, higher maintenance cost, reduced product quality, less production output related result. For the question given training plans related to maintenance the response of most of the respondents agree that you are acquainted with the installed machines of the enterprise, you think training is very significant for efficient maintenance and the company has low cost and accessible training facilities. And some of the respondents are disagreed that the company has well-trained and experienced technician, planned training programs are given on maintenance and operators take training to help them to do their task. It can be concluded that even if the company have accessible training facilities they don't give proper training to technicians and machine operators due to this case the company doesn't meet production objective, a prolonged machine downtime, higher maintenance cost, reduced product quality, less production output. In equipment optimization of the company most of the respondents are disagree that I use information gathered from the equipment's to identify and prioritize maintenance actions, I monitor equipment availability through operating time, scheduled downtime, and unscheduled downtime and I compare the total units produced against the defective units produced by equipment on an ongoing basis and some of the respondents are agree that I fully apply effort to improve equipment capacity, uptime, and production cycle time. In general, it can be conclude that the majority of the respondents disagreed with the idea regarding the effect of equipmentoptimization on company production performance. The outcomes of poor equipment management are low level of performance, reliability, and high production process stoppages, and increase repair cost.

The majority of participants disagree that you planned shutdowns for significant repairs in advance for the question given maintenance planning and scheduling. You have appropriate spare parts for maintenance, the total amount of work orders has been delayed due to poor plans, the machine is maintained within a short time when it fails, and the enterprise has programs to evaluate the effectiveness of the maintenance that is carried out,and some of the respondants agree that when the maintenance task is finished, the technician who performed the task reports the actual working time,downtime andused material. You set priorities for maintenance job tasks and the responsibility for planning the preventive work orders relies on maintenance planner. In planned preventive maintenance most of the respondents are agreed that the maintenance department supports machine operators perform their own preventive maintenance, there is an isolated shift, or part of a shift, kept each day for maintenance activities, cleaning, and oiling, tightening and inspection of equipment are carried out regularly and daily maintenance applies help achieve good quality products from our equipment and schedule contract and some of the respondents are disagree that there is a devoted time period where the equipment is shut down for maintenance and there is a devoted time period where the production and maintenance members meet to plan for maintenance. In production performance most of the respondents are disagreed that our company has improved the ability to produce above designed capacity on some equipment’s, our company has reduced the costs involved in printing products, our company has improved the ratio of finished products to raw materials,our company has reduced the amount of scrap generated by our equipment’s and some of the respondents are agreed that Our company has reduced the number of products returned due to quality defects and Machine stoppage reduces intended or planned production capacity.

The enterprise takes maintenance practices as a key function but there are limitations on maintenance record keeping and documentation activities, poor workflow, skill gap on maintenance technicians, old machinery, lack of spare parts focus on planned preventive maintenance and training to maintenance workers.Since developing and applying a good maintenance policies or developing a maintenance framework is important tothe enterprise'seffectiveness. Therefore, improve the availability of the machines can be meet by concentrating on preventing maintenance.

Generally, productivity is an important component in any manufacturing company thorough to recognize higher manufacturing performance which is a competitive advantage(Oliveira, 2014), discovered that the implementation of good equipment maintenance system among manufacturing industries improves productivity, thus satisfying customer requirements.

According to (Andrews, 2012) OEE measurement is an effective way analyzing of a single machine or an integrated manufacturing system. Besides that, OEE created by (V.Palanisamy and Jose Ananth Vino, 2015), focuses on waste, and on inefficiencies in the manufacturing process; in essence, it emphasizes the lost time when the equipment isn't making. To be competitive, company performance depends on the availability of their production facilities and the need to improve and optimize their productivity.

The result of the OEE indicates that the company is lagging behind the world-class OEE standard by 46.44%, 50.83% and 54.78 respectively in each year. The survey shows that 95% of the machines maintenance activities were done after machine break down occur and there is unavailability of proper maintenance strategy. Due to these conditions there was a low performance of machines in their speed as well as in their availability resulting reduction of Overall Equipment Effectiveness.

Therefore, this research pursues to examine the problems of prolonged machine downtime which lag behind the attainment of the maintenance system implemented in Berhanena Selam printing enterprise and discover maintenance system framework as a policy to help ensure the production stability of the operational scheme at high efficiency and thus improve production.

CHAPTER FIVE

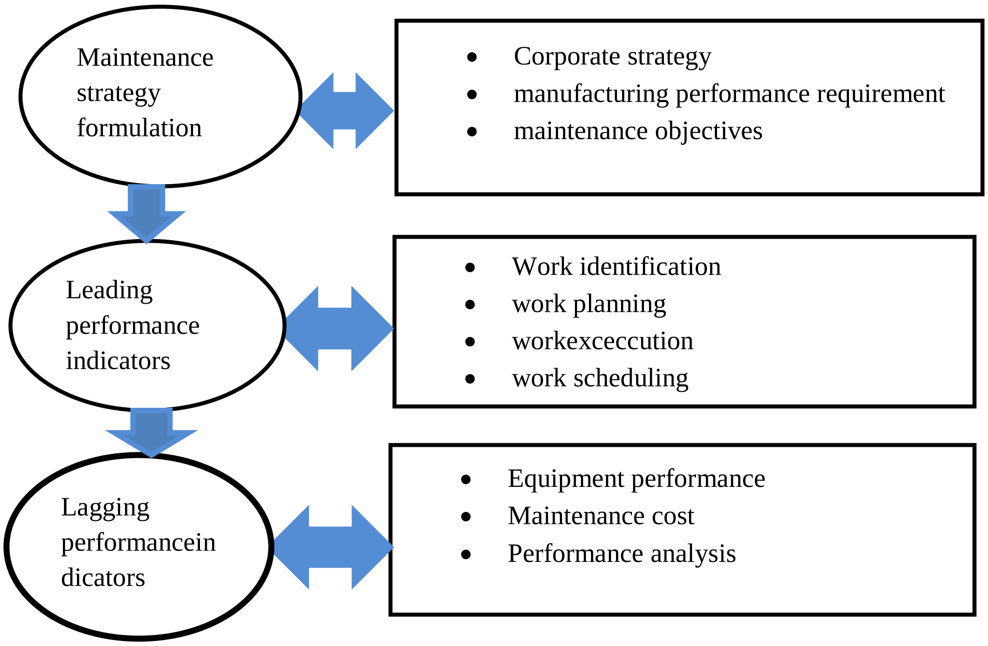
5. Developing Maintenance Performance Conceptual Framework

5.1 Introduction

According to the research findings, the company has gaps in planned preventive maintenance, maintenance record keeping and documentation, machine age, low quality spare parts, poor breakdown maintenance, a lack of spare parts, skill gaps among maintenance technicians, and a lack of technician training. In general, the organization lacks a defined and all-encompassing maintenance strategy framework.

5.2 Developing conceptual frame work

(P.Muchiri, 2011)established a conceptual framework for maintenance performance that identifies the primary procedures that lead the maintenance function to produce the performance demanded by manufacturing objectives. The conceptual framework encourages maintenance goals to be aligned with manufacturing and corporate goals. Maintenance alignment with manufacturing, maintenance effort/process analysis, and maintenance results performance analysis are the three primary elements of the conceptual framework. The initial goal of the conceptual framework is to connect maintenance goals with manufacturing strategies. The performance requirements of the production system can be well-defined by researching the company's requirements.The use of cognitive mapping to investigate the cause and effect links between strategic essentials is critical. The fundamental essentials that are central in the administration of the maintenance function are summarized in the maintenance performance framework. The essentials ensure that the proper work is identified and done effectively for defined results that meet the manufacturing performance requirements. Each stage is critical to the maintenance function's proper management. The maintenance process (leading) and maintenance results (lagging) are both important indications for assessing the maintenance function's performance.



Figur 5.1: The performance measurement framework for the maintenance function (P.Muchiri, 2011)

(H.A.Yuniarto, 2009) stated ship Maintenance Performance measurement framework. The efficacy of the ship maintenance performance measurement method is meant to satisfy the needs of the maintenance process in a marine organization, this can be accomplished by examining ship maintenance performance measurement from a variety of perspectives, including financial, customer, employee, and safety. The three properties of the designed SMPM framework are as follows: First, all of the criteria in the framework are used in parallel to measure maintenance performance with no preference between them; second, these criteria were chosen to complement each other in order to cover major aspects affecting the maintenance performance of the entire organization without overlap or duplication; and third, the framework considers the entire organization system as a whole to understand how its various aspects interact; and finally, the framework considers the entire organization system as a whole to understand how its various aspects interact. Furthermore, the framework connects the organization's strategy to total maintenance effectiveness and standards.

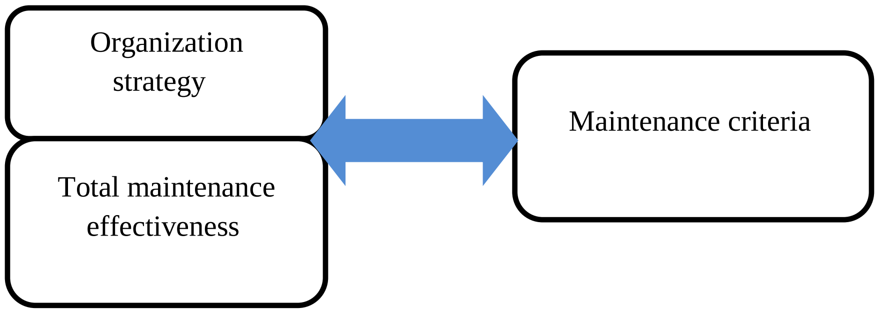


Figure 5.2: linking organization strategy, total maintenance effectivenss, and maintenance criteria

(H.A.Yuniarto, 2009)

(Marquez, 2007)develops the maintenance management process as the definition of a maintenance strategy from a business strategy in order to reduce maintenance indirect costs and improve maintenance implementation. This part is all about efficiency, which is defined as providing better maintenance for the same cost.

The creation of a four-functioned maintenance management framework with eigh blocks. Effectiveness, efficiency, assessment, and improvement are the functions of this function. Maintenance objectives and associated key performance measures challenge effectiveness first. The strategy and performance measurement balanced score card method was developed to eliminate inconsistency of overarching business plan with operational objectives. This aids in the establishment of specific key performance indicators for a business that are aligned with its strategic goals. The second type of asset is one that is prioritized using a risk number analysis. The third step involves addressing higher-impact weak points through root cause failure investigation. The fourth step is Designing a preventive maintenance plan for a specific system necessitated determining its function, the ways in which these functions can fail, and then establishing a set of suitable and effective preventive maintenance tasks based on system safety and economy considerations. The optimization of maintenance planning and scheduling is the fifth phase. The maintenance tasks are carried out in the sixth phase. The cost of an asset over its whole life lifetime is calculated in the seventh phase. The final phase is continual improvement and maintenance management, which is demonstrated by e maintenance's accurate and precise data flow. The maintenance management framework recommends TPM as another method for continuous improvement and maintenance management.

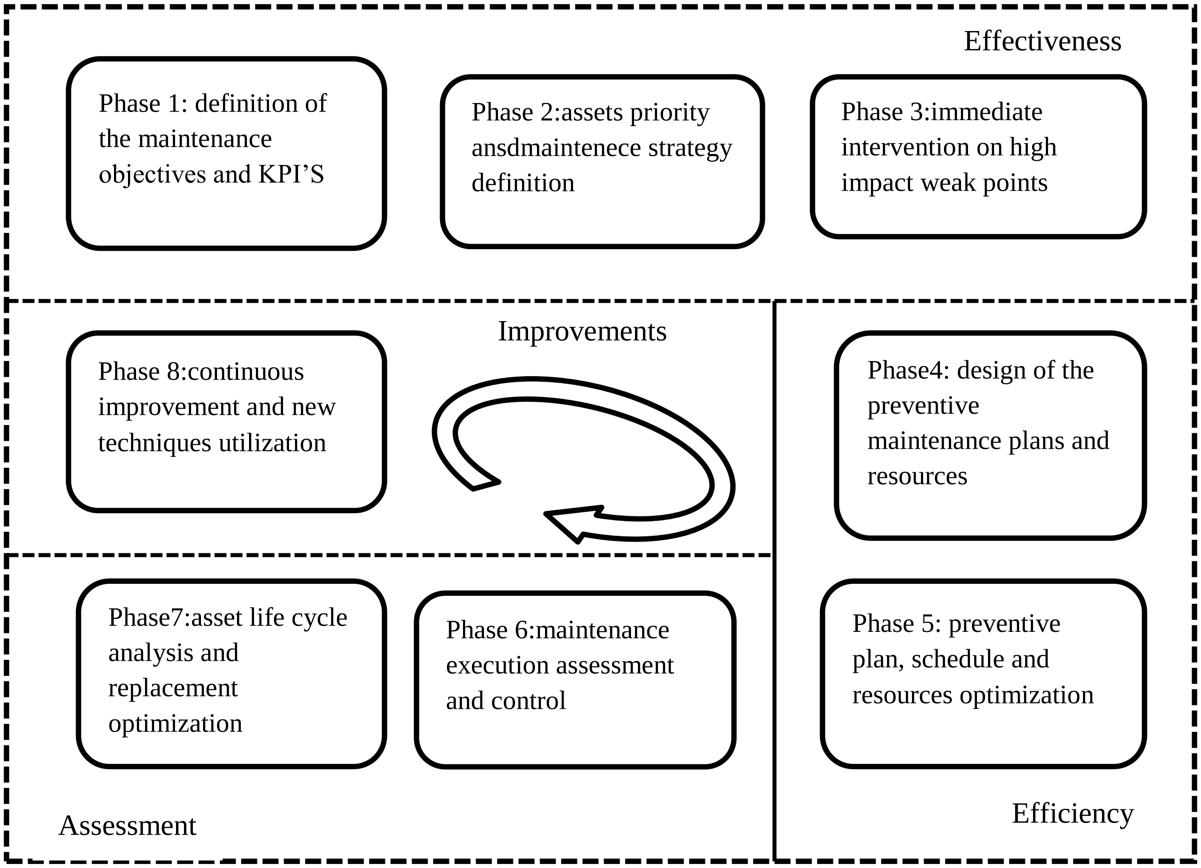


Figure 5.3: Maintenance management framework (Marquez, 2007)

The maintenance performance conceptual framework described in this research outlines important parts and procedures that drive the maintenance function to produce the performance required by manufacturing goals.The company conceptual framework was developed in response to a gap discovered through data analysis and debate. The following are the components that make up a maintenance framework.

a) **Maintenance strategy formulation**

This will be determined based on the company's business goals. Knowing the major function of the company's maintenance department requires identifying the maintenance strategy. The goals include improving maintenance professionals' skill and expertise, ensuring the availability of spare parts and other substrates, increasing machine availability, satisfying customers, and ensuring the safe storage of machineries.

b) Identify existing problem area

The efficacy of the total production process is determined by availability and OEE. The availability, performance, and OEE of the machine in the company are all quite low, as revealed by the data analysis and discussion.

c) Identifying Root Causes of the problem

According to the Cause and Effect diagram, the organization can reduce downtime problems by eliminating the identified potential causes. Countermeasures to eradicate the underlying causes were outlined in Table 4.15 based on the discovered root causes of the primary problems in the causes and effect diagram:

d) Select maintenance strategy

According to the discussion with the maintenance staff, planned preventative maintenance is the greatest way to improve the equipment's performance. And the organization chose autonomous maintenance because it allows operators to reduce reaction time and do planned maintenance, which means that the operators' maintenance abilities and knowledge will grow. It also improves machine availability, performance, and OEE by making greater use of manufacturing resources.

e) Maintenance WorkflowSystem

The workflow is an information system for the maintenance business that is critical to the job's success(Wireman, 2005). Because the maintenance workflow is inefficient, a new and improved maintenance work flow is presented. The company's improved maintenance workflow is depicted in the diagram below.

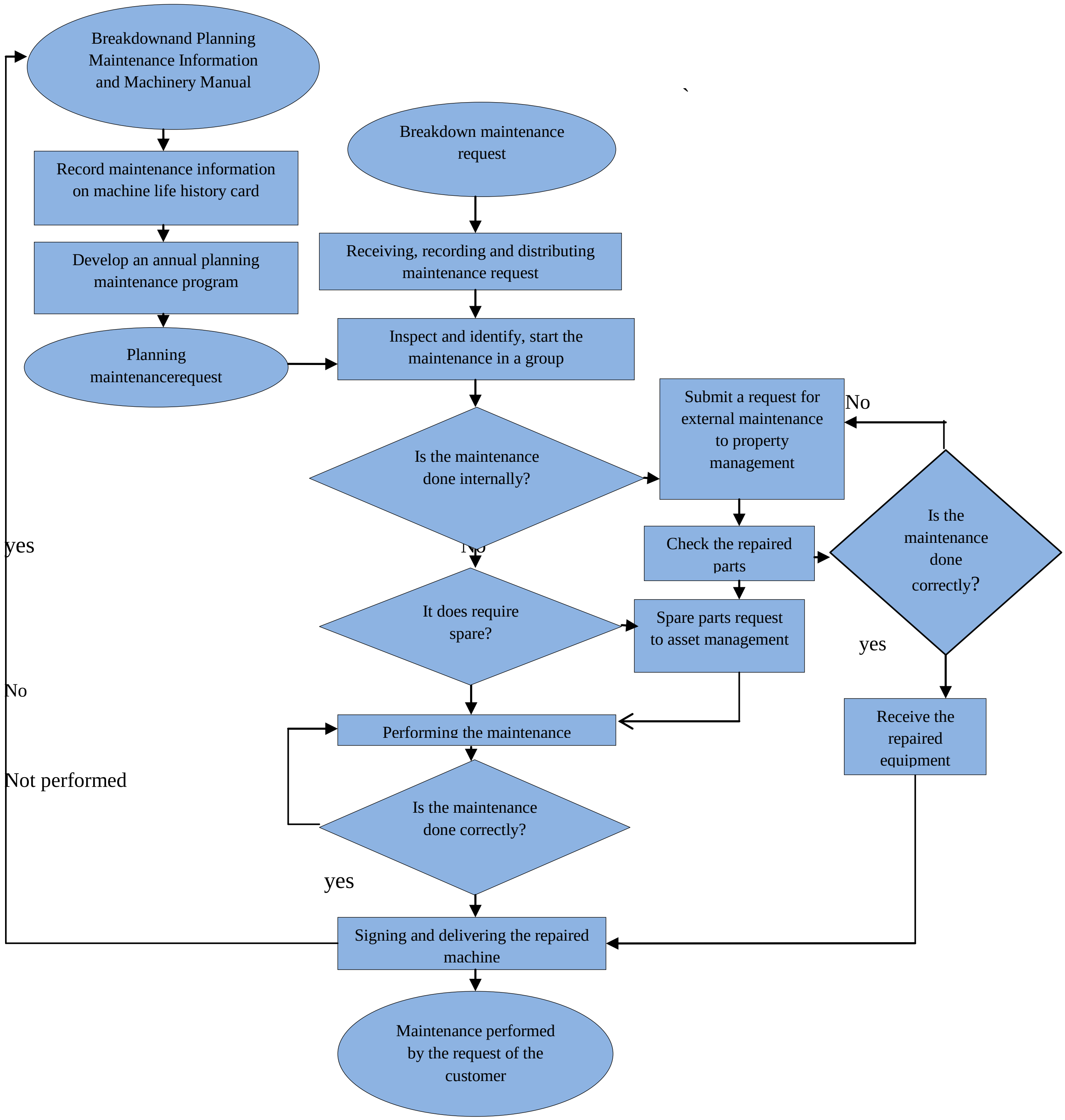


Figure 5.4: Proposed Workflow

f) Computerized Maintenance Management Information System

It's a piece of software that keeps track of information regarding a company's maintenance operations in a computer database. This data is meant to assist maintenance staff in performing their jobs more efficiently and to assist management in making more informed decisions. It was once used to determine which machines needed maintenance and which storerooms had the spare components they required, as well as evaluating the cost of machine breakdown repair versus preventive maintenance for each machine, perhaps resulting in improved resource allocation.

g) Set Key Maintenance Performance Indicators (KPI)

KPI is a quantifiable and strategic assessable value that shows anenterprise's crucial achievement aspects. It is difficult for any company to evaluate performance in meaningful ways and make changes to solve performance-related concerns without KPIs. Well-defined performance indicators can help identify performance gaps between present and desired levels of performance, as well as progress toward decreasing the gap.

The following are the selected performance indicators derived from maintenance objectives;

Table 5.1: Proposed Key Maintenance Performance Indicators

Key Performance Indicators	Units	Description	Baseline Targets
Availability of equipment	%	MTBF/(MTBF+MTTR)	90%
Overall Equipment Effectiveness (OEE)	%	Availability(A)*performance rate(Pr)*qualityrate(Qr)	85%
Break down severity	%	Break down/direct maintenance cost	10%
Work request response rate	%	Work request remaining in request status for <5days/total work request	80%
Schedule complains	%	Percentage of work order accomplished in planned period before late finish date.	95%
Quality of execution/rework	%	Percentage of maintenance work requiring rework	< 3%
Number of practical training giving	%	Percentage of practical training giving to worker in the budget year	100%

h) Continuous Improvement

First, establish maintenance objectives, then establish maintenance management and resource management, a computerized maintenance management information system, maintenance implementation, maintenance completion, and key maintenance performance indicators. Finally, assess and improve the maintenance system. Following this loop ensures that the maintenance system is continually improving, resulting in increased machine efficiency and productivity.

The suggested framework will help the organization by putting in place a system to improve machine performance, availability, product quality, reduce downtime, and increase production.

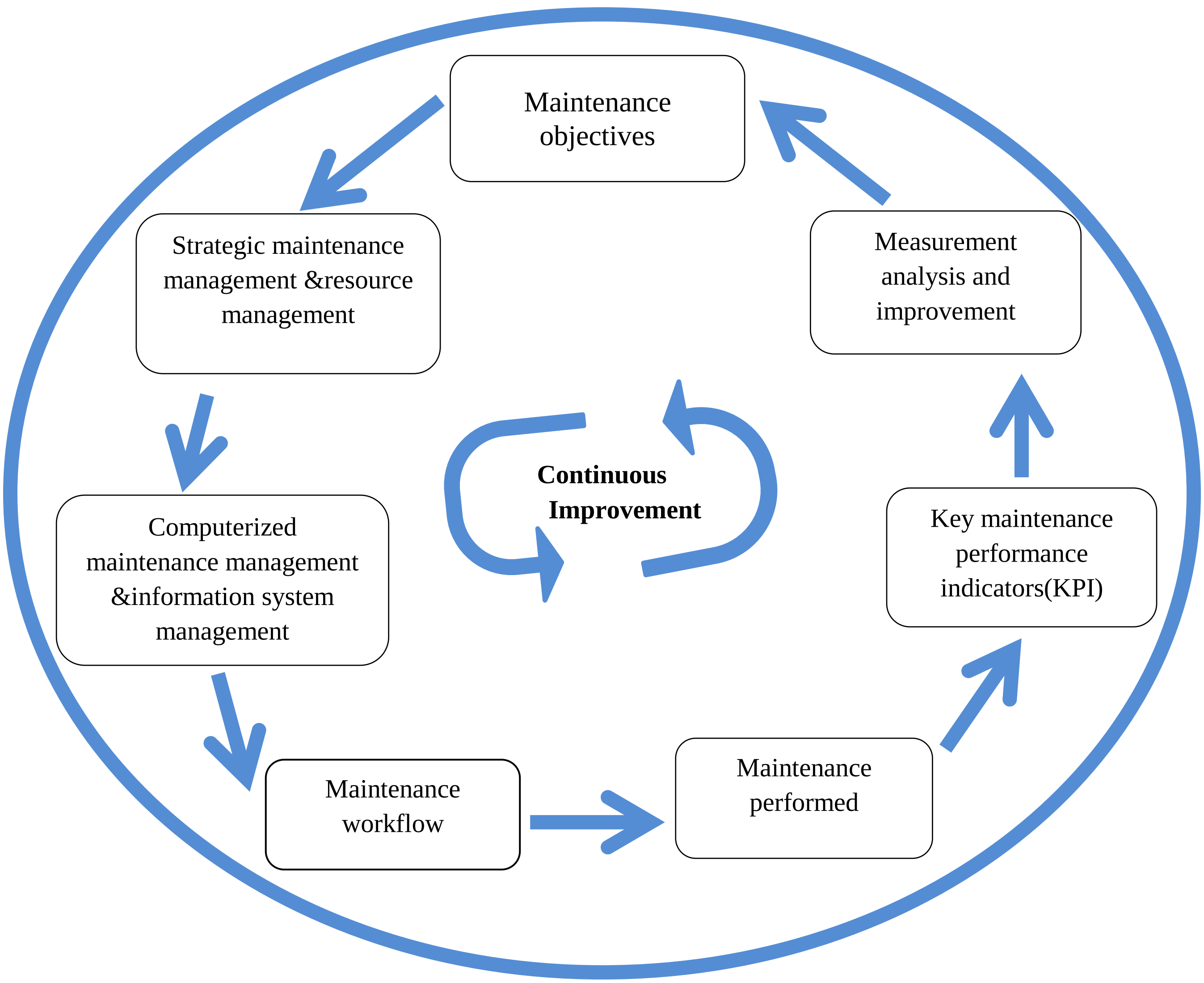


Figure 5.5: proposed conceptual framework of maintenance system

5.3 Implementation Procedure

During implementation, the actions listed below must be followed.

1. Clarifying and definite top management concerning to the significance of maintenance purpose for enterpriseachievement.
2. Create a team from different levels of workers experience and education
3. Provide team training on the following topics:
   - What are the primary factors to the company's success?
   - What is the goal of the maintenance department?
   - Tools and procedures for conducting a cause-and-effect investigation
   - What are the many sorts of maintenance strategies, as well as their benefits and drawbacks?
4. The authorized team will begin putting the maintenance system framework in place. The following will be the rules:
   - Set maintenance objectives;
   - create a strategy for maintenance management and resource management;
   - create a computerized maintenance management information system;
   - create a maintenance workflow;
   - perform maintenance;
   - create key maintenance performance indicators; and
   - prepare the performance indicators' data recording foramts. This will simplify the process of reviewing key performance metrics.
   - Measure, analyze, and improve the work done
   - based on the results Improve the system on a continuous basis based on the results

5.3.1System Implementation Schedule

The maintenance system implementation schedule covers the activities starting from the system evaluation and approval up to and effectiveness of the system. it is envisaged that the complete implementation program requires a total of fourmonths.

The formation of the implementation team, training program and financial arrangement will be made at the same time as the evaluation and approval of the system. Preparing a checklist for training may take one month.

Training of team will start after evaluation and approval and continue to the start of trail working of the system this may take two months. The system will start immediately after the trial effectiveness of the system this may also take one month.Details of the implementation schedule are shown in Figure.

Table 5.2: Implmentation Schedule of The System

s/r	Activity	Month			
		1	2	3	4
1	Implementation team formation				
2	Preparing training checklist				
3	Training				
4	System trial				
5	Fix the system				

5.3.2System Implementation Cost

System implementation costs are the costs of system management, consultancy services, and personal training. These costs are spread during the system implementation period based on the proposed start and duration of their respective activitiesshown in the implementation schedule. The cost of the consultant is estimated at Birr 150,000, system management and personal training cost is estimated at Birr 85,000.Therefore, the total system implementation cost is estimated at Birr 235,000.

5.4 Validation Of The Proposed Framework

Accordingly, to make judgements regarding the suggested framework's soundness, as well as if it can match the company and achieve the intended result, the frameworks were validated through discussions with the company's executive, maintenance director, and technical experts. During the conversation, the importance of the framework, its viability, and where the framework could need to be improved were all highlighted.

The framework is important and sustainable, according to the discussion, because it addresses practical issues. All maintenance department employees and equipment operators must receive training in order to apply the maintenance system successfully and efficiently.

CHAPTER SIX

6. Conclusion and Recommendation

6.1 Conclusion

Businesses, government civil service organizations, and public enterprises all face problems in the modern period that determine their long-term viability and success or failure. These include shifting the power balance from the seller to the consumer, changing customer wants on a regular basis, low-cost initiatives, and outstanding service being the success of many institutions, as well as technology and competitors joining the market in a variety of forms and quality. The establishment of a customer-oriented system that responds to the needs of the above-mentioned factors is one of the most important concerns that must be addressed.

The manufacturing industry has long been aware of the need of maintenance. Quality and cost were greatly improved by limiting and minimizing equipment deterioration and failures thanks to a better maintenance system. Because fewer goods were rejected owing to equipment failure, the cost of rework and repairs was lowered. As a result, the overall effectiveness of the equipment has significantly enhanced. The utilization of effective maintenance conceptualframework to enhance the overall equipment effectiveness(OEE) of manufacturing equipment is the subject of this thesis.As a result, the process reviews the present method for providing effective, efficient, and high-quality customer service, as well as the customers' demands and difficulties, as well as the problems and weaknesses to providing efficient maintenance conceptual framework. Poor maintenance activity is a problem for the system, according to the company's analysis. The company's focus on proactive maintenance methods is limited, as its documenting of maintenance operations and history, knowledge and skill gaps in how to maintain technological machines, and the lack of a comprehensive and standard maintenance strategy. The result of the Overall Equipment Effectiveness indicats that the company is lagging behind the world class OEE standards by 46.44%, 50.83 ad 54.78% respectivey in each year.A good maintenance conceptual framework can help a company enhance its performance and availability, which leads to higher OEE and productivity. The conclusion was reached that implementing a good maintenance conceptualframework can reduce wasted production time, improve productivity, reduce losses, increase the company's competitiveness, reduce machine downtime, reduce maintenance cycle time, reduce machine setup time, increase machine life, and increase company profit.

6.2. Recommendation

Based on the findings of the thesis, the case company proposed that the following steps be taken in order to increase the company's productivity.

- The organization should apply the provided maintenance conceptual framework to reduce machine stoppage and enhance productivity.
- In order to increase their production perfomance, the company should emphasis on improving their employee empowerment strategies, such as involving machine operators in routine maintenance and continuous improvement activities, implementing regular training plans to impart relevant skills to employees, and operating through small groups made up of members from different divisions of the company.
- An advanced computerized maintenance management system should be used by the organization. As a result, proper usage of the Computer Maintenance Management Systemoffersworkersthroughadditional structure in their job.
- To increase productivity, the enterprise should put more focus on improving their proactive maintenance practice, planned preventive maintenance practices, such as requiring equipment shutdown for maintenance, requiring time for the production and maintenance groups to meet to plan for maintenance, and performing repetitive cleaning, oiling, tightening, servicing, and inspection of the machines.

6.3 Future Work

There are numerous manufacturing industries in our country, and these industries have many machines, however owing to a lack of attention paid to machine maintenance, machine service life is short, product quality is poor, and output capacity is lowered. According to the findings of this study Overall Equipment Effectiveness, availability, and machine performance are predictors of productivity enhancement. Future research could focus on how these maintenance strategies affect other continuous improvement programs like Total quality management.

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Appendix-I

Machine availability based on planned operating time and actual operating time

Sr.No	Months	Loading/Planned operating time	Actual operating time	Total downtime	Availability
1	July 2018	7,157.85	4,321.18	2,836.670	60%
2	August 2018	7,121.68	5,506.45	1,615.230	77%
3	September 2018	4,315.99	2,227.44	2,088.550	52%
4	October 2018	6,678.04	4,141.17	2,536.870	62%
5	November 2018	6,901.38	4,501.24	2,400.140	65%
6	December 2018	6,143.4	3,615.57	2,527.830	59%
7	January 2019	8,233.77	4,563.12	3,670.650	55%
8	February 2019	8,058.31	5,199.96	2,858.350	64%
9	March 2019	7,319.17	4,523.68	2,795.490	62%
10	April 2019	6,261.02	3,221.50	3,039.520	51%
11	May 2019	6,714.21	3,934.28	2,779.930	59%
12	June 2019	6,268.62	3,283.39	2,985.230	52%
Average		81,173.44	49,038.98	32,134.46	60.4%

Data source: company annual report (2018/2019)

Appendix-II

Performance of the printing machine based on their planned impression and actual impression

Sr.No	Months	Planned impression	Actual impression	Performance
1	July 2018	18,680,100	13,686,822	73%
2	August 2018	18,595,221	14,940,981	80%
3	September 2018	15,845,234	4,596,481	29%
4	October 2018	17,254,126	7,356,771	43%
5	November 2018	17,254,126	13,859,902	80%
6	December 2018	17,254,126	12,415,999	72%
7	January 2019	19,354,317	13,629,781	70%
8	February 2019	19,354,317	14,287,489	74%
9	March 2019	18,595,221	6,529,767	35%
10	April 2019	17,254,126	12,709,220	74%
11	May 2019	17,254,126	13,632,939	79%
12	June 2019	17,254,126	12,192,654	71%
Average		213,949,166	139,838,806	65.0%

Data source: company annual report (2018/2019)

Appendix-III

Machine availability based on planned operating time and actual operating time

Sr.No	Months	Loading/Planned operating time	Actual operating time	Total downtime	Availability
1	July 2019	7,157.85	4,120.93	3,036.92	58%
2	August 2019	7,121.68	5,255.91	1,865.77	74%
3	September 2019	4,315.99	1,927.13	2,388.86	45%
4	October 2019	6,678.04	3,891.05	2,786.99	58%
5	November 2019	6,901.38	4,300.92	2,600.46	62%
6	December 2019	6,143.4	3,315.14	2,828.26	54%
7	January 2020	8,233.77	4,312.76	3,921.01	52%
8	February 2020	8,058.31	4,899.72	3,158.59	61%
9	March 2020	7,319.17	4,323.07	2,996.10	59%
10	April 2020	6,261.02	2,970.78	3,290.24	47%
11	May 2020	6,714.21	3,634.11	3,080.10	54%
12	June 2020	6,268.62	2,933.08	3,335.54	47%
Average		81,173.44	45,884.60	35,288.84	57%

Data source: company annual report (2019/2020)

Appendix-IV

Performance of the printing machine based on their planned impression and actualimpression

Sr.No	Months	Planned impression	Actual impression	Performance
1	July 2019	18,680,100	13,052,554	70%
2	August 2019	18,595,221	14,261,175	77%
3	September 2019	15,845,234	3,976,769	25%
4	October 2019	17,254,126	6,912,433	40%
5	November 2019	17,254,126	13,243,090	77%
6	December 2019	17,254,126	11,384,311	66%
7	January 2020	19,354,317	12,881,969	67%
8	February 2020	19,354,317	13,462,545	70%
9	March 2020	18,595,221	6,240,193	34%
10	April 2020	17,254,126	11,720,098	68%
11	May 2020	17,254,126	12,592,799	73%
12	June 2020	17,254,126	10,891,800	63%
Average		213,949,166	130,843,824	61%

Data source: company annual report (2019/2020)

Appendix-V

Machine availability based on planned operating time and actual operating time

Sr.No	Months	Loading/Planned operating time	Actual operating time	Total downtime	Availability
1	July 2020	7,157.85	3,890.72	3,267.13	54%
2	August 2020	7,121.68	5,010.65	2,111.03	70%
3	September 2020	4,315.99	1,606.79	2,709.20	37%
4	October 2020	6,678.04	3,600.60	3,077.44	54%
5	November 2020	6,901.38	4,050.49	2,850.89	59%
6	December 2020	6,143.4	2,974.80	3,168.60	48%
7	January 2021	8,233.77	4,017.44	4,216.33	49%
Average		46,552.11	25,151.49	21,400.62	54%

Data source: company sevenmonths report (2020/2021)

Appendix-VI

Performance of the printing machine based on their planned impression and actual impression

Sr.No	Months	Planned impression	Actual impression	Performance
1	July 2020	18,680,100	12,323,391	66%
2	August 2020	18,595,221	13,595,696	73%
3	September 2020	15,845,234	3,315,724	21%
4	October 2020	17,254,126	6,396,449	37%
5	November 2020	17,254,126	12,471,983	72%
6	December 2020	17,254,126	10,215,571	59%
7	January 2021	19,354,317	11,999,864	62%
Average		124,237,250	70,206,769	57%

Data source: company seven months report (2020/2021)

Appendix-VII

Defect and Rework in all four main products of the printing production process

s.no	Months	Order Qty	Missing part of serial	Miss alignment	Back image no seen clearly	Total defective	Defective percentage
1	July 2018	39,345,100	1,129,923	556,859	10,570	1,697,352	4.3%
2	August 2018	38,245,100	332,991	25,564	72,690	430,245	1.12%
3	September 2018	36,345,100	536,874	103,963	8,093	648,930	1.78%
4	October 2018	36,345,100	335,877	125,673	6,065	467,616	1.28%
5	November 2018	39,045,100	237,502	81,604	12,017	331,124	0.84%
6	December 2018	37,345,100	299,494	106,766	40,740	447,000	1.19%
7	January 2019	36,262,100	438,257	84,866	6,606	529,729	1.46%
8	February 2019	35,543,100	328,465	122,900	5,931	457,297	1.28%
9	March 2019	37,851,100	328,571	25,301	71,940	425,813	1.12%
10	April 2019	38,046,100	222,169	538,474	10,404	771,047	2.02%
11	May 2019	36,365,100	315,672	24,308	69,116	409,096	1.12%
12	June 2019	37,278,100	450,536	87,244	40,667	578,448	1.55%
Average		448,016,200	4,956,331	1,883,522	354,839	7,193,697	1.66%

Data source: company annual report (2018/2019)

Appendix-VIII

Defect and Rework in all four main products of the printing production process

s.no	Months	Order Qty	Missing part of serial	Miss alignment	Back image no seen clearly	Total defective	Defective percentage
1	July 2019	40,656,603	1,271,163	591,663	10,900	1,873,726	4.60
2	August 2019	39,519,937	374,615	27,162	74,962	476,738	1.21
3	September 2019	37,556,603	603,983	110,461	8,346	722,790	1.92
4	October 2019	37,556,603	377,862	133,528	6,255	517,644	1.37
5	November 2019	40,346,603	267,190	86,704	12,393	366,287	0.90
6	December 2019	38,589,937	336,931	113,439	42,013	492,383	1.27
7	January 2019	37,470,837	493,039	90,170	6,812	590,022	1.57
8	February 2020	36,727,870	369,523	130,581	6,116	506,221	1.37
9	March 2020	39,112,803	369,642	26,882	74,188	470,713	1.20
10	April 2020	39,314,303	249,940	572,129	10,729	832,798	2.12
11	May 2020	37,577,270	355,131	25,827	71,276	452,234	1.20
12	June 2020	38,520,703	506,853	92,697	41,938	641,488	1.66
Average		462,950,073	5,575,872	2,001,242	365,928	7,943,042	1.72

Data source: company annual report (2019/2020)

Appendix-IX

Defect and Rework in all four main products of the printing production process

s.no	Months	Order Qty	Missing part of serial	Miss alignment	Back image no seen clearly	Total defective	Defective percentage
1	July 2020	41,968,107	1,285,287	599,058	11,037	1,895,382	4.52
2	August 2020	40,794,773	378,777	27,501	75,899	482,177	1.18
3	September 2020	38,768,107	610,694	111,841	8,450	730,986	1.89
4	October 2020	38,768,107	382,060	135,197	6,333	523,589	1.35
5	November 2020	41,648,107	270,159	87,788	12,547	370,494	0.90
6	December 2020	39,834,773	340,674	114,857	42,538	498,070	1.25
7	January 2021	38,679,573	498,517	91,297	6,898	596,712	1.54
Average		280,461,547	3,766,169	1,167,540	163,701	5,097,411	1.82

Data source: company seven months report (2020/2021)

Appendix-X

OEE analysis report of 2018/2019 twelve months

Sr.No	Months	OEE analysis report			
		Availability (%)	Performance (%)	Quality (%)	OEE (%)
1	July 2018	60	73	95.6	41.8
2	August 2018	77	80	98.8	60.8
3	September 2018	52	29	98.2	14.8
4	October 2018	62	43	98.7	26.3
5	November 2018	65	80	99.1	51.5
6	December 2018	59	72	98.8	41.9
7	January 2019	55	70	98.5	37.9
8	February 2019	64	74	98.7	46.7
9	March 2019	62	35	98.8	21.4
10	April 2019	51	74	97.9	36.9
11	May 2019	59	79	98.8	46.0
12	June 2019	52	71	98.4	36.3
Average		60	65.36	98.34	38.56

Appendix-XI

OEE analysis report of 2019/2020 twelve months

Sr.No	Months	OEE analysis report			
		Availability (%)	Performance (%)	Quality (%)	OEE (%)
1	July 2019	58	70	95.4	38.73
2	August 2019	74	77	98.79	56.29
3	September 2019	45	25	98.08	11.03
4	October 2019	58	40	98.63	22.88
5	November 2019	62	77	99.1	47.31
6	December 2019	54	66	98.73	35.18
7	January 2020	52	67	98.43	34.29
8	February 2020	61	70	98.63	42.11
9	March 2020	59	34	98.8	19.81
10	April 2020	47	68	97.88	31.28
11	May 2020	54	73	98.8	38.94
12	June 2020	47	63	98.34	29.11
Average		57	61	98.28	34.17

Appendix-XII

OEE analysis report of 2020-2021 seven months

Sr.No	Months	OEE analysis report			
		Availability (%)	Performance (%)	Quality (%)	OEE (%)
1	July 2020	54	66	95.48	34.03
2	August 2020	70	73	98.82	50.49
3	September 2020	37	21	98.11	76.23
4	October 2020	54	37	98.65	19.71
5	November 2020	59	72	99.1	42.09
6	December 2020	48	59	98.75	27.97
7	January 2021	49	62	98.46	29.91
Average		54	57	98.18	30.22

Appendix-XIII

Comparison between world classes OEE and company

OEE Factors	World class	Case company (BSPE)		
		2018/2019	2019/2020	2020/2021
Availability	90.0%	60.4	57	54
Performance	95.0%	65.0	61	57
Quality	99.9%	98.34	98.28	98.18
OEE	85%	38.56	34.17	30.22

Appendix- XIV

Summary of Respondent's General Information

Questionnaires	**Frequency**	**Percent**
Questionnairs respond	115	82
Questonnaires not respond	25	18
Respondent Age		
Less than 30 years	28	24
Between 31-40	38	33
Between 41-50	32	28
Above 51	17	15
Respondent's Highest Levels of Education		
Certificate	22	19
Diploma	55	48
Undergraduate/Degree	32	28
Postgraduate/Master	6	5
Respondent's Work Experience		
Less than one years	13	11
Between 1&5 years	21	18
Between 6&10 years	30	26
Above 10 years old	51	44

Appendix-XV

Bahir Dar University

Bahir Dar Institute of Technology

School of Research and Graduate Studies

Faculty of Mechanical and Industrial Engineering

Questionnaire

Questionnaire on Machine productivity improvement through maintenance

Dear valued respondent,

I am a postgraduate student at Bar Dar university institute of technology in Addis Ababa branch pursuing a master's degree. I am now collecting data for my thesis **"to establish machine productivity improvement through maintenance".** In sight of the above, I am simply requesting you to collaborate in answering the questionnaire which I will offer in the questionnaires attached here-with. Kindly read the accompanying instructions and answer to the questions as provided for. This will help me collect the necessary data for analysis, hence, achieve the objectives of the study.

The information that you provide will remain sound and will be used solely for this research and not for any other purpose whatever.

Your response and collaboration in this matter will be highly respected.

Instruction

a. There is no need to write your name
b. Please put a check mark **(**√**)** in the box next to your choice

Questionnaire

Part A: demographic information

Please, put tick mark (√**)** in the box provided against your choice

1) What is your age group?
    a) Less than 30 years [ ]
    b) Between 31-40 years [ ]
    c) Between 41-50 years [ ]
    d) Above 51 years [ ]
2) Specify your highest level of education?

a) Certificate [ ]

b) Diploma [ ]

c) Degree [ ]

d) Master [ ]

e) Others (Specify) ____________________

3) How many years of working experience do you have?

a) Less than one year [ ]

b) 1-5 years [ ]

c) 6-10 years [ ] d) Above 10 years [ ]

Part B: Challenges of machinery maintenance

1. The statements below relate to challenges of machinery maintenance in BSPE. Using the key (Where, 5= strongly agree, 4= agree, 3= undecided, 2= disagree and 1=strongly disagree), put a check mark (√) next to the options you want to be your top priority.

Description		Respondents				
		Strongly Disagree	**Disagree**	**Undecided**	**Agree**	**Strongly Agree**
1	The distance of the machines from the stock room does not have important role in manipulating the machine stoppage.					
2	The existing tools are old and doesn't help to repair the machine during maintenance.					
3	Primacies is not given to maintenance plan and the primacy is given to production without ensuring good maintenance practice.					
4	The mechanics are lacking attention to particulars and they are only concentrating towards a rapid repair work towards equipment failure.					
5	The reporting order is suitable to carry about the maintenance and production improvement.					
6	The administration doesn't give sufficient attention to training of manpower to improve the mechanic abilities.					
7	The mechanics refer documents and manuals of manufacturers of the machines while doing maintenance activities.					

Part C: Training plans related to maintenance.

Description		Response				
		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1	The company have well trained and experienced technician					
2	Scheduled training programs are given on maintenance					
3	Maintenance technicians well skilled.					
4	Production workers are/operators get training to perform their task correctly.					
5	You are familiar with the installed machines of the company.					
6	You think training is significant for effective maintenance.					
7	The company have low cost and accessible training facilities.					

Part D: Equipment optimization

1. The statements below relate to equipment optimization in BSPE. Using the key (Where, 5= strongly agree, 4= agree, 3= undecided, 2= disagree and 1=strongly disagree), put a tick mark (√) under the choices you prefer.

Description		Response				
		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1	I use information gathered from the equipment's to identify and prioritize maintenance actions.					
2	I monitor equipment availability through operating time, scheduled downtime and unscheduled downtime.					
3	I compere the total units produced against the defective units produced by equipment on an ongoing basis.					
4	I fully apply effort to improve equipment capacity, uptime and productive cycle time.					

Part E: Maintenance planning and scheduling

1. The statements below relate to maintenance planning and scheduling in BSPE. Using the key (Where, 5= strongly agree, 4= agree, 3= undecided, 2= disagree and 1=strongly disagree), put a tick mark (√) under the choices you prefer.

Description		**Response**				
		Strongly Disagree	**Disagree**	**Undecided**	**Agree**	**Strongly Agree**
1	You planned shutdowns for major repairs in advance.					
2	The maintenance task is accomplished, the technician that accomplished the tast reports the real working time,used materials, and stoppage.					
3	You have appropriate spare parts for maintenance.					
4	The entire quantity of work orders have been delayed due to poor or incomplete plans.					
5	Youset priorities for maintenance job tasks.					
6	The equipment's are maintained within a short time when the equipment's failed.					
7	The company have programs to assess the efficiency of the maintenance that is carried out.					
8	Duty for scheduling the preventive work instructions relies on maintenance planner.					

Part F:Planned Preventive maintenance

1. The statements below relate to planned preventive maintenance in BSPE.

Description		Response				
		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1	The maintenance department supports machine operators perform their own preventive maintenance.					
2	There is an isolated shift, or part of a shift, kept each day for maintenance activities.					
3	Cleaning, oiling, tightening and inspection of equipment are carried out regularly.					
4	There is a devoted time period where the equipment is shut down for maintenance.					
5	Daily maintenance applies help achieve good quality products from our equipment and schedule contract.					
6	There is a devoted time period where the production and maintenance members meet to plan for maintenance.					

Part G:Production performance

1. The statements below relate to production performance in BSPE.

Description		Response				
		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1	Our company has improved the ability to produce above designed capacity on some equipment’s.					
2	Our company has reduced the costs involved in printing products					
3	Our company has improved the ratio of finished products to raw materials.					
4	Our company has reduced the number of products returned due to quality defects.					
5	Our company has reduced the amount of scrap generated by our equipment’s.					
6	Machine stoppage reduces intended or planned production capacity					
7	Total production time is affected by the amount of machine downtime.					

This is the last page of the questionnaire… thanks so much for your time.