



ADDIS ABABA UNIVERSITY
COLLEGE OF BUSINESS AND ECONOMICS
SCHOOL OF COMMERCE
DEPARTMENT OF PROJECT MANAGEMENT

ASSESSMENT OF PREVENTIVE MAINTENANCE PROJECTS
ON PRODUCTION LINES PERFORMANCE: IN THE CASE OF
EAST AFRICA BOTTLING SHARE COMPANY ADDIS
ABABA PLANT

IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR
THE AWARD OF MASTER DEGREE IN PROJECT
MANAGEMENT

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BY ROBEL WOLDE

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**A RESEARCH PROJECT WORK SUBMITTED TO
ADDIS ABABA SCHOOL OF COMMERCE GRADUATE
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ARTS DEGREE IN PROJECT MANAGEMENT**

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BY ROBEL WOLDE

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DECLARATION

I, ROBEL WOLDE hereby declare that this thesis entitled – assessment of preventive maintenance projects on production lines performance: in the case of east Africa bottling share company Addis Ababa plant - is my own paper work and that it has not been submitted before anywhere for any award.

Robel Wolde

Date:

Letter of Certification

This is to certify that Robel Wolde carried out this research entitled — assessment of preventive maintenance projects on production lines performance: in the case of east Africa bottling Share Company Addis Ababa plant. This work is original and suitable for submission to the award of Master of Arts Degree in Project Management.

Teklegiorgis Assefa (PhD)

Date:

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List of Abbreviations and Acronyms

BD-Break down
CBM-Condition Based Monitoring
CMMS-Computerized maintenance management system
CCBA-Coca Cola Beverage Africa
DT-Down time
EABSC-East Africa Bottling Share Company
ETB-Ethiopian Birr (local currency for Ethiopia)
EBI-Empty bottle inspection system
FBI-full bottle inspection system
PM-Preventive Maintenance
KPI-Key performance indicator
ME-Machine efficiency
MC-Maintenance cost
OPF-Operational Failure
PQ-Production quantities
RGB-Returnable Glass Bottles
PET- Polyethylene terephthalate
SAP-System application and Products integrated software
SD-Shutdown Maintenance
TPM- Total Productive Maintenance

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Abstract

The aim of this study is to assessment of preventive maintenance projects on production lines performance: in the case of east Africa bottling Share Company Addis Ababa plant. In addition to this it described the major challenges regarding production line performance, and preventive maintenance practice at EABSC and challenges on preventive maintenance projects execution. The study used descriptive approach and potential respondents include all 13 machine operators, 7 line technicians, 8 line electricians, 5 mechanical specialists, 4 electrical specialists, 6 Line process engineers, 4 maintenance planners, 3 maintenance controllers and 1 CBM expert for gathering primary data by questionnaire and secondary data gathered from SAP (system application and process) system and Company reports to analyze the effect of preventive maintenance projects has on production line performance by selecting machine efficiency and production volume. The numeric data was analyzed using descriptive statistics in SPSS, and the qualitative data was analyzed using content analysis. The survey was done on four production lines in EABSC Addis Ababa plant by taking sample size of 51. The results showed that poor checklist execution practice is the major factors affecting production line performance by 25.5% from other factors. Survey and Sap data showed that 60.7% respondents agreed skipping overhaul maintenance can affect the line performance and after overhaul maintenance line performance improved. 80.4% respondents agreed that CBM reduces number of breakdowns. It's recommended that EABSC should focus on preventive maintenance projects in order to improve production lines performance. It's better to avail tools for operators to do some tightening tasks on production lines machineries. Also not skipping usage based maintenance according to original equipment manufacturer recommendation is recommended. Strengthen CBM department with new technologies and equipment is good for better failure analysis so to reduce machine breakdown and save cost.

Key words: *Autonomous maintenance, Condition based monitoring, Machine efficiency, Preventive maintenance, Time based maintenance, Usage based maintenance*

CHAPTER I

INTRODUCTION

This study is entitled to explain and assess preventive maintenance projects in production lines performance in the case of east Africa bottling Share Company Addis Ababa plant. It's focused on the implementation challenges facing preventive maintenance projects.

This chapter gives an overview and the summary of the whole research thesis. It briefly state the background of the study, background of the organization, objectives of the study, statement of the problem, research questions , scope, significance and limitation of the study.

1.1 Background of the Study

The beverage industry manufactures drinks and ready to drink products such as bottled water, soft drinks, energy drinks, milk products, coffee and tea-based products, nutritional beverages and alcohol. This companies need to operate in highly dynamic environments where key resources are scarce and uncertainty in business opportunities is common. Nonalcoholic beverage industries, like other businesses, are founded to profit the provider or owners of the enterprise. This suggests that in today's competitive business environment, producers must capitalize on every conceivable advantage. In order to be competitive in the market, companies has to perform and deliver products to their customers by using different types of machineries. Keeping such machineries safe is very important to maintain the market share value. For that matter, companies use difference maintenance strategies and management approaches (Jacob Ben. 2021).

According to European standards, maintenance is defined as “Combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform a required function.” (EN 13306: 2001). The endurance of every manufacturing organization is its maintenance. Without the correct maintenance practice and maintenance strategy, an organization's asset or equipment cannot sustain its performance and health, and may depreciate quickly, affecting the organization's productivity and profitability. This is followed by establishing optimal maintenance practices at the corporate level in order to improve productivity and performance of the production

lines. It is well understood that paying attention to maintenance practices is critical to achieving corporate goals. According to Vavra (2016), it is conceivable to follow maintenance best practices, which will save time and money while increasing productivity over time. Maintenance practices and strategies are critical components of manufacturing and processing operations.

Maintenance practices and strategies are a set of ideas that include an ordered series of maintenance approaches meant to improve equipment performance or efficiency and reduce machine downtime. According to Mobley (2008), the absence of a well-established maintenance program, a lack of an acceptable maintenance budget, and insufficient spares are all factors. Some of the biggest issues that most industrial firms have when establishing maintenance practices and policies are lack of availability, improper technical and operational trainings, a lack of technical and operational knowledge, and the use of outmoded training techniques. These issues eventually lead to a lack of sustainable production performances, which causes two artisans to refuse future assignments, a decrease in productivity, an increase in operational error, increased negligence, and a lack of due attention when fixing maintenance problems.

Maintenance management is the direction and organization of resources with the goal of controlling the availability and performance of industrial plants to a certain level (Parida & Kumar, 2006). Planning, scheduling, coordinating, and controlling are all aspects of maintenance management activities. The maintenance strategy is determined by various elements, including the maintenance goals, the nature of the facility or equipment to be maintained, work flow patterns, and the work environment.

Effective maintenance, according to Wikstan and Jonansson (2006), can lessen the consequences of failure and increase the life of a system. Maintenance policies, which can be defined as the plans of action used to provide direction and instructions for carrying out additional maintenance actions required by a system (Waeyenbergh and Pintelon, 2002), are referred to as maintenance policies. Corrective maintenance (CM) is a type of maintenance policy in which maintenance operations such as repair or replacement are performed on a system to restore it to normal operation after it has failed (Paz and Leigh, 1994). However, due to the possibility of abrupt failures, this policy results in high levels of system breakdown

and expensive maintenance and replacement costs. PM, another maintenance policy, is an alternative to CM. PM is typically planned and executed after a set period of time or after a specific system has been used to lessen the likelihood of failure (Kimura, 1997). When PM procedures are used, Mechefske and Wang (2001) assert that most systems are maintained while a major portion of their useful life remains.

1.2 Statement of the Problem

Maintenance methods are agreed to have an effect on production performance through their impact on quality, speed, cost, and efficiency. Poor maintenance methods can have an impact on production. In manufacturing facilities, performance, unscheduled machine breakdown, machine downtimes, and frequent operational errors occur (Bellgran and Säfsten, 2010). Preventive maintenance (PM) is essential for preventing potential equipment or machinery stoppages and disturbances in everyday operations. PM stressed the need of total employee involvement for businesses. Maintenance practices have been agreed upon. Impacts manufacturing performance by influencing quality, speed, cost, and efficiency. Poor maintenance methods can have an impact on production performance by causing unscheduled machine breakdowns, downtimes, and frequent operational errors in manufacturing plants (Kimura, 1997).

Both preventive and corrective maintenance strategies are applied in EABSC manufacturing area machines. Keeping this in mind, the below figure shows the machine breakdown rate of each production line on the year of 2020, 2021 and 2022. According to CCBA standard, the machine breakdown rate should be less than 5% per year. This value was achieved by line 1 and line 3 on the year of 2022. The rest values as per the figure is above the standard value. Three years average of line 1, line 3, line 4 and line 5 is 5.3%, 7.46%, 14.48% and 8.98% respectively. When this three years averages are compared to the standard 5%, they are all above the desired value.

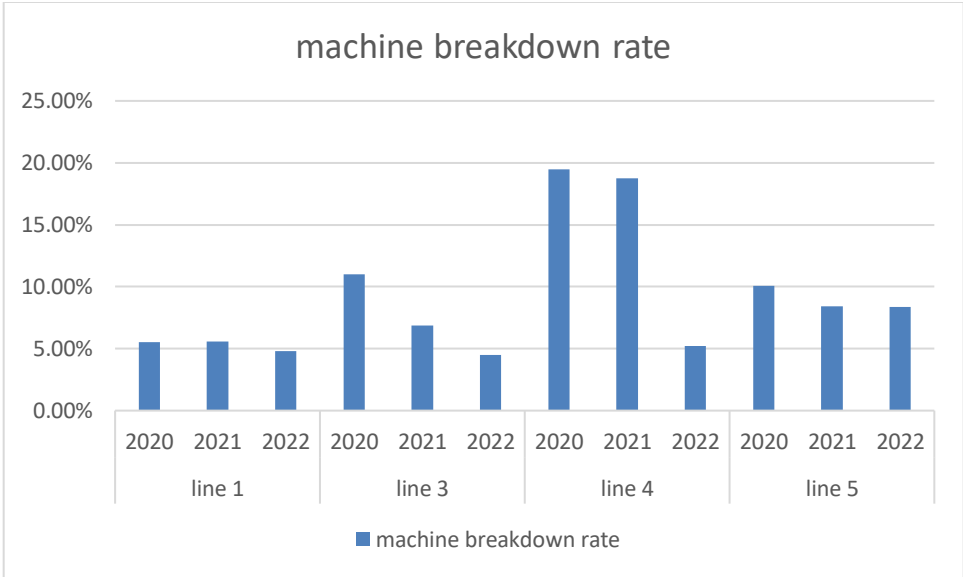


Figure 1 - Machine breakdown rate of production lines
Source (EABSC SAP system)

The below figure illustrates the number of machine breakdowns per year which is recorded on SAP system per production line. The three years average number of breakdown on line 1, line 3, line 4 and line 5 is 556, 1408, 1761 and 592 respectively. This is high breakdown number and can affect the performance of production lines.

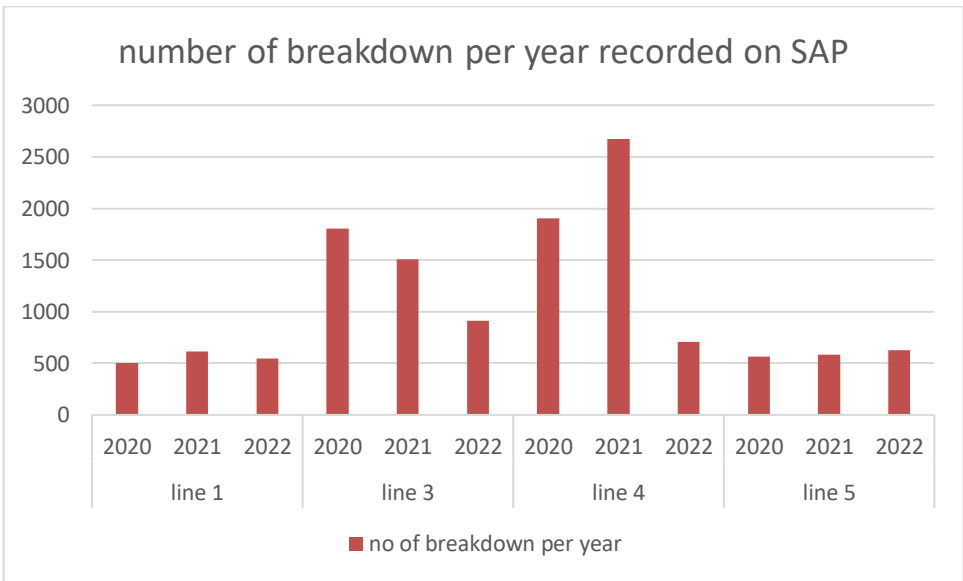


Figure 2 - Number of breakdowns per year on production lines
Source (EABSC SAP system)

According to Wireman (1990, p.98), It is a series of operations conducted on plant equipment, machinery, and systems prior to failure in order to protect them and avoid or eliminate any degradation in their operational conditions. The aim of this research is to investigate the effect of preventive maintenance project on production lines performance in case of East Africa Bottling Share Company Addis Ababa plant. The study seeks to determine the challenges on preventive maintenance practice execution, the relation between usage based maintenance project to production line machine efficiency and the effect of condition based monitoring maintenance on reducing machine breakdown in the four production lines of EABSC.

1.3 Research Questions

The study attempted to assess preventive maintenance projects on production lines performance, research addressed the following questions:

1.3.1 General Research Question

- How preventive maintenance projects are applied to affect production lines performance?

1.3.2 Specific Research Questions

- What are preventive maintenance projects applied in EABSC?
- What are the challenges of preventive maintenance projects execution?
- What is the effect of usage based maintenance projects on machine efficiency and production volume?
- What is the effect of condition based monitoring maintenance on machine breakdown reduction?

1.4 Objective of the Study

1.4.1 General Objectives

The study is generally aimed at assessing preventive maintenance projects on production lines performance in case of EABSC Addis Ababa plant.

1.4.2 Specific Objectives

The specific Objectives of the study are the following:

- To Describe preventive maintenance projects employed in EABSC
- To Identify the challenges of preventive maintenance projects execution
- To Investigate the effect of usage based maintenance on machine efficiency and production volume
- To Determine the effect of Condition based monitoring (CBM) maintenance on machine breakdown reduction

1.5 Definition of terms

Maintenance: The collection of all technical, administrative, and managerial actions taken during an item's life cycle to keep it in, or restore it to, a state in which it can perform the required function (EN 13306: 2001).

Maintenance strategy: The management strategy utilized to achieve the maintenance objectives (Växjö, 2010).

Production: The process of combining and transforming various resources employed in the organization's production/operations subsystem into value-added products/services in a regulated way in accordance with the organization's policies.

Downtime: The entire amount of time that the item is not in a proper operational condition (Moblely, 2004).

Machine efficiency / equipment effectiveness: When evaluating a manufacturing system, equipment efficiency is a standard indicator. To boost product throughput, the efficiency is normally maximized by running the equipment at its maximum speed for as long as possible (Moblely, 2004).

Availability: likelihood that an object will be available for use when needed (Mobley, 2004).

1.6 Significance of the Study

The research will provide important answers for east Africa bottling Share Company and other beverage industries who face same challenges on preventive maintenance projects execution and impact on production lines performance. When addressed properly, the results to the challenges will improve machine efficiency, reduce machine breakdowns, and improve line productivity by volume. The study is also significant for academic and researches that it can be used as a reference for future projects regarding preventive maintenance by companies who apply this maintenance strategy for the well-being ness of their machineries.

1.7 Scope / Delimitation of the Study

The scope of the study is limited to the extent of comprehending the assessment of preventive maintenance projects on production lines performance, describing the preventive maintenances projects used, identify challenges regards preventive maintenance execution, evaluate the relation between usage base maintenance and machine efficiency, and determine the effect of CBM in breakdown reduction.

1.8 Limitations of the study

It was a difficult task to return all of the questionnaires in such a short amount of time. Production machine operators and line technicians are mostly busy in following the production and maintaining the operation as well as the machines to run smoothly. Gathering secondary data, categorizing reports depending on the research's needs, and getting information from the appropriate person were all time-consuming activities that kept the study moving. Furthermore, there are various peak seasons in CCBA for increased product demand. It is possible that the equipment will not be able to produce evenly during the rainy and dry seasons. As a result, the EABSC's output may fluctuate from season to season, and the study was unable to determine the effects of seasonal dynamics on maintenance practice and production outputs.

Similarly, the study is limited to EABSC, even though the same notion of industrial culture applies to other bottling and brewing enterprises. Also due to location, resource and time shortage, this study is limited to Addis Ababa plant rather than all plants under EABSC.

1.9 Organization of the Study

This paper is organized in five chapters which follows similar arrangement as most research papers. I.e. chapter one – discusses about the proposal section, chapter two- reviews the literature and related works by other scholars, chapter three- depicts the research design and methodology, chapter four- presents the data result & analysis and in the final chapter which is chapter five – forwards recommendation and reflections on the issues discussed in the data gatherings.

CHAPTER II

LITERATURE REVIEW

2.1 Theoretical literature review

2.1.1. Concept of maintenance

In general, 'Maintenance' could be defined as the integration of all possible technical and administrative actions, including planning, supervising, monitoring, and controlling, with the goal of retaining an item, a system, or a machine in its original functional state, allowing it to perform the intended functions (hikmet 2022). According to Duffuaa (2010), Maintenance is described as the mix of operations that keep or restore equipment, assets, or a system in a state where it can fulfill its specified function. It is an essential aspect in product or service quality and can be used as a business strategy for success. Maintenance is an important aspect to increase productivity by reducing such downtimes and improving equipment performance. Maintenance is basically a set of processes and practices that help in the continuous and efficient operation of assets. The major benefits of maintenance are:

- Increase in the life of the equipment and other assets.
- Optimization of asset performance.
- Reducing unwanted downtimes, thus increasing production
- Minimizing cost

2.1.2. Types of maintenance

Mobley (2004) states that industrial and process plants commonly use one of two methods of maintenance management: (1) run-to-failure or (2) preventive maintenance.

2.1.2.1 Run-to-failure

The concept of run-to-failure management is plain and easy. When a machine fails, repair it. This "if it aren't broke, don't fix it" approach to plant maintenance has been a major aspect of plant operations since the first manufacturing plant was erected, and it appears to be logical (Mobley, 2004, page 2). A facility that employs run-to-failure management does not spend money on maintenance until an equipment or system fails. Run-to-failure is a reactive management strategy

that involves waiting for a machine or piece of equipment to break before performing any maintenance. It is, in fact, a low-maintenance management strategy. Few plants practice true run-to-failure management. Even in a run-to-failure scenario, factories virtually always undertake fundamental preventative actions (such as lubrication, machine adjustments, and other adjustments). However, under this management style, machines and other plant equipment are not rebuilt, nor are substantial repairs undertaken until the equipment fails to function (Mobley, 2004).

The majority of maintenance is remedial. Repairs are always required. However, better improvement and preventive maintenance can lessen the requirement for emergency adjustments. Because there is little human judgment involved, a shaft that is plainly split into pieces is reasonably easy to maintain. Troubleshooting and diagnostic fault detection and isolation cost a significant amount of time in maintenance. When an issue is evident, it is typically simple to fix. Intermittent failures and hidden problems take more time, but diagnostics can determine the causes and then rectify them. From the standpoint of preventive maintenance, the problems and causes that lead to failures serve as targets for eradication through feasible preventive maintenance. The objective is to detect potential problems before they become catastrophic failures and to rectify the flaws at the lowest possible cost. This brings us to the middle three fingers, which are the branches of preventive maintenance. (Mobley, 2004, page 2)

2.1.2.2 Preventive Maintenance

Preventive maintenance is described as operations performed on a time- or machine-run-based schedule to detect, prevent, or mitigate degradation of a component or system in order to prolong or extend its useful life by managing degradation to an acceptable level (Sullivan, 2010). According to Wireman (1990, p.98), It is a series of operations conducted on plant equipment, machinery, and systems prior to failure in order to protect them and avoid or eliminate any degradation in their operational conditions. Systematic inspection, discovery, repair, and prevention of minor flaws before they become significant flaws. Preventive maintenance (PM) is an essential part of any maintenance effort. Within a maintenance organization, it typically accounts for a significant amount of total maintenance effort. PM is defined as the care and servicing provided by maintenance personnel to keep equipment/facilities in a satisfactory operational state by providing for systematic inspection, detection, and correction of incipient

failures prior to their occurrence or development into major failure (Dhillon, 2006).

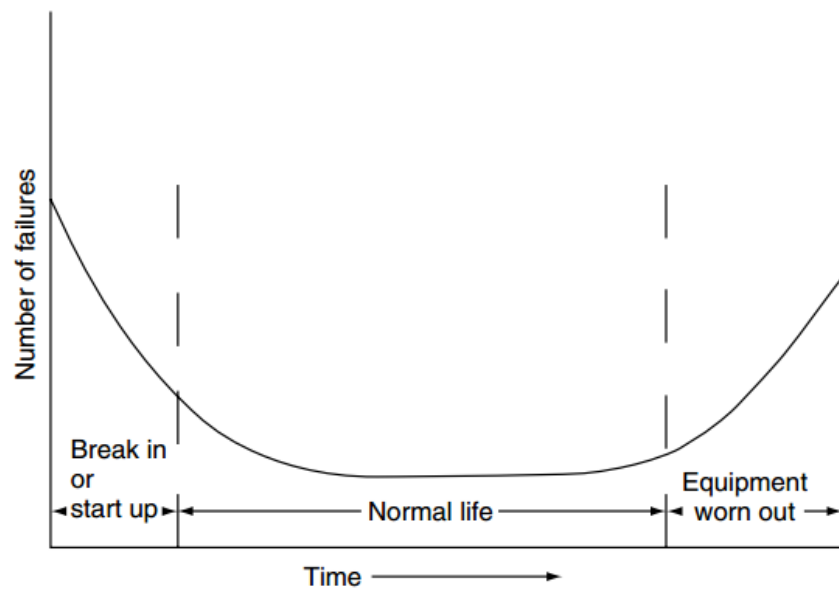


Figure 3 – bathtub curve

Source: (Mobley, 2004, page 3)

Figure 3 illustrates an example of the statistical life of a machine-train the mean time to failure (MTTF) or bathtub curve suggests that a new machine has a high likelihood of failure during the first few weeks of operation due to installation issues. Following this initial stage, the likelihood of failure is relatively low for an extended period of time. Following this normal machine life term, the likelihood of failure grows dramatically with time. Machine repairs or rebuilds are scheduled in preventative maintenance management based on the MTTF statistic (Mobley, 2004, page 3).

2.1.3. Types of preventive maintenance

There are different classifications of preventive maintenance types according to different authors and books. According to Mobley 2004, preventive maintenance is classified as:

- Time driven preventive maintenance
- Predictive maintenance
- Equipment driven preventive maintenance

This maintenance types have many forms has been shown in the figure below. For this research purpose it's selected based on preventive maintenance types actually being implemented in EABSC Addis Ababa plant.

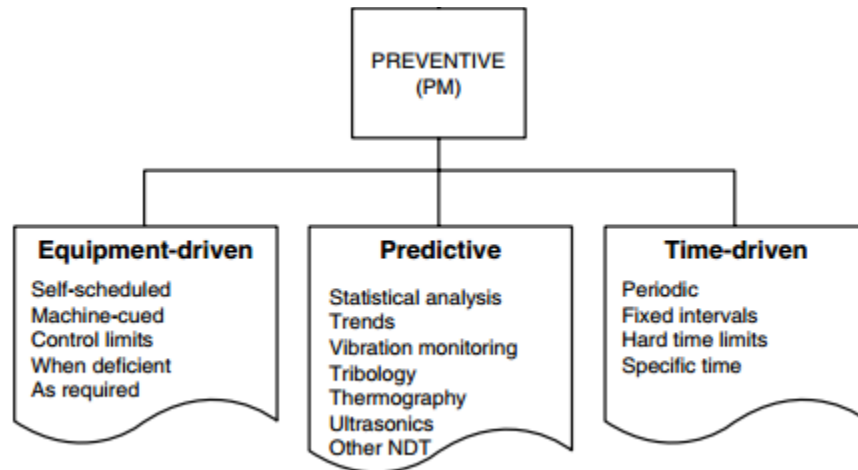


Figure 4 – structure of preventive maintenance
Source: (Mobley, 2004, page 9)

2.1.3.1 Time based (periodic) preventive maintenance

Periodic maintenance is time-based (scheduled) maintenance activity which is a continuous activity that aids in the longevity of any piece of equipment. It entails evaluating and servicing machinery or equipment on a regular basis to ensure top performance. A periodic maintenance procedure plan is a document that details the maintenance activities and processes for a specific piece of machinery or equipment. It specifies what sorts of parts are covered by scheduled maintenance, how frequently each item should be checked, and what specific tests or measurements should be performed. Every piece of equipment in your organization that requires periodic maintenance should have its own periodic maintenance process plan (Dhillon, 2006).

One of the tools for time based preventive maintenance is CMMS. According to Sullivan, 2010, a computerized maintenance management system (CMMS) is a type of management software that conducts management and tracking capabilities for O&M activities. Most logistical duties done by maintenance employees and management are automated by CMMS systems. CMMS systems have numerous options and numerous advantages over manual maintenance tracking methods. Depending on the system's complexity, typical CMMS functions may include the following:

- Creation of work orders, priority, and tracking by equipment/component.
- Historical tracking of all work orders generated, sortable by equipment, date, responder, and so on.
- Keeping track of regular and unscheduled maintenance tasks.
- Keeping all maintenance procedures and warranty information organized by component.
- Preventive maintenance work orders can be generated on a calendar or during runtime.

According to Sullivan, 2010, one of the most significant advantages of the CMMS is the removal of paperwork and manual tracking operations, allowing the building crew to become more productive. It should be emphasized that a CMMS's capability is defined by its capacity to gather and store information in an easily accessible way. A CMMS does not make judgments; rather, it delivers the best information to the O&M management to influence the operational efficiency of a facility (Sullivan, 2010). The following are some of the advantages of implementing a CMMS:

- ✓ Early detection of potential problems, resulting in fewer failures and customer complaints.
- ✓ Increasing the level of planned maintenance tasks, allowing for more efficient use of staff resources.
- ✓ Improving inventory control and anticipating spare parts to eliminate shortages and reduce existing inventory.
- ✓ Maintaining optimal equipment performance, which lowers downtime and extends equipment life.

2.1.3.2 Usage based (fixed interval) preventive maintenance

According to Mobley 2004, scheduled, fixed-interval preventive maintenance tasks should be employed only where there is an opportunity to reduce failures that cannot be recognized in advance, or when production requirements require it. Fixed-interval maintenance should be distinguished from fixed-interval inspection, which may detect a threshold condition and launch condition monitoring operations. Fixed interval activities include 3,000-mile oil changes and

48,000-mile spark plug changes on an engine, whether the adjustments are required or not. Because no two pieces of equipment and operational settings are comparable, this could be extremely wasteful. What is appropriate in one setting may not be appropriate in another.

2.1.3.3 Condition based monitoring maintenance

According to Sullivan 2010, Predictive maintenance (condition based monitoring) seeks to predict the onset of a degradation process in order to rectify it before considerable deterioration occurs in the component or equipment (Sullivan, 2010). The diagnostic capabilities of predictive maintenance technologies have improved in recent years as sensor technologies such as infrared (IR) thermography, infrared thermometers, ultrasonic detection, oil analysis equipment, and so on have advanced. These improved technologies, improvements in component sensitivities, size reductions, and, most crucially, cost reductions have opened up a completely new area of diagnostics for the operational and maintenance practitioner. (Sullivan, 2010).

The foundations for condition monitor maintenance are provided by statistics and probability theory. Trend detection through data analysis frequently rewards the analyst with insight into the causes of failure and preventive steps that will aid in the avoidance of future failures. Stadium lights, for example, burn out in a relatively short period of time. If 10% of the lights have burned out, it can be safely expected that the remaining lights will fail shortly and should be changed as a group rather than individually. (Mobley, 2004)

According to Sullivan 2010, the benefits of predictive maintenance are numerous. A well-executed predictive maintenance program will almost completely eliminate catastrophic equipment breakdowns. We will be able to schedule maintenance activities in order to reduce or eliminate overtime costs. We will be able to reduce inventory and order parts as needed far in advance to satisfy downstream maintenance needs. We can optimize equipment functioning, lowering energy costs and enhancing plant reliability. Previous research has suggested that a fully operating predictive maintenance program can save 8% to 12% more than a preventive maintenance-only program. Depending on the facility's current maintenance procedures, current equipment reliability, and facility downtime, there is no doubt that establishing a proper preventive maintenance program might save much more than 18%. Depending on a facility's reliance on reactive maintenance and material condition, it might potentially see savings of 30% to 40%.

Indeed, independent surveys show that implementing a functional predictive maintenance program results in the following industrial average savings:

- ✓ 10 times return on investment
- ✓ 25% to 30% reduction in maintenance costs
- ✓ 70% to 75% Breakdown elimination
- ✓ 35% to 45% reduction in downtime
- ✓ 20% to 25% increase in output.

Sullivan (2010) estimates that the cost of maintenance activities might range from 15 to 70% of overall production expenses.

According to Taylor (2011), driving down maintenance expenses has become a credo in many firms, and properly so in some circumstances. However, simply lowering maintenance expenditures will not necessarily fulfill your organization's goals. The mission and objectives of the company's upkeep must be considered. One method is to tie maintenance expenses to the overall cost of production or, in the case of single or similar product lines, to the number of units produced. In interdivisional or inter firm benchmarking, for example, a maintenance cost per ton of output is a commonly used figure.

$$\text{Direct Maintenance Cost per Unit Output} = \frac{\text{Total Direct Maintenance Cost}}{\text{Total Production Units}}$$

Thermography

According to Sullivan 2010, Infrared (IR) thermography is the method of creating visual images that depict fluctuations in the IR radiance of objects' surfaces. Similarly to how different materials and colors absorb and reflect electromagnetic radiation in the visible light spectrum (0.4 to 0.7 microns), any object at temperatures above absolute zero emits IR energy (radiation) proportionate to temperature. Its current temperature. The infrared radiation spectrum is widely accepted to exist between 2.0 and 15 microns. A two-dimensional visual image reflecting of the IR radiance from the surface of an object can be formed using an equipment that contains detectors sensitive to IR electromagnetic radiation.

Because infrared radiation falls outside of the visible light spectrum (to which our eyes are sensitive), it is invisible to the human eye. An infrared camera or similar technology allows us to examine an item outside of the visible light spectrum based on its temperature and proportional imitation of IR radiation. There are many different types of IR detection devices, each with its own set of capabilities, design, and price. Furthermore, simple temperature measurement systems that detect IR emissions but do not create a visual image or an IR profile are produced (Sullivan 2010).

- ✓ Spot Radiometer (Infrared Thermometer) - Although not commonly thought of in the area of thermography, IR thermometers use the same basic concepts as higher end equipment to determine the temperature of an item based on IR emissions. These devices do not offer an image of an object's thermal profile, but rather a value representing the objects or area of interest's temperature.
- ✓ Infrared Imager - As previously said, the capabilities, design, cost, and functionality of equipment vary widely. There are differences in the material, operation, and design of IR detectors. At the most basic level, IR detecting devices are divided into two categories: imagers and cameras with radiometric capability. A basic IR imager can detect an object's IR emissions and convert this information into a visual image. It is not capable of analyzing and quantifying precise temperature data. When temperature numbers are unimportant and the object's temperature profile (represented by the image) is all that is required to describe an issue, this form of IR detecting device can be useful (Sullivan 2010).

Ultrasonic Analysis

According to Sullivan 2010, Ultrasonic, or ultrasounds, are sound waves with frequencies greater than 20 kHz. Sound waves in this frequency range are higher than what humans can ordinarily hear. Airborne ultrasound is detected by non-contact ultrasonic detectors used in predictive maintenance. The frequency spectrums of these ultrasounds span from 20 to 100 kHz. Ultrasounds, in contrast to IR emissions, travel a relatively short distance from their source. Ultrasounds, like IR emissions, move in a straight line and cannot penetrate solid objects. Ultrasounds produced by vacuum systems are produced within the system. A tiny percentage of

these ultrasonic waves escape from the vacuum leak and can be detected if the monitoring is done close to the source or the detector gain is suitably adjusted to improve detection effectiveness. In addition to detecting system vacuum or fluid leaks, ultrasonic wave detection can be used to define abnormal conditions within a system or component. Ultrasonic detecting sensors can also be utilized to monitor bearing condition. According to research conducted by the National Aeronautics and Space Administration (NASA), a 12-50x increase in the amplitude of a monitored ultrasonic frequency (28 to 32 kHz) can provide an early signal of bearing damage (Sullivan 2010).

Vibration Analysis

According to Sullivan 2010, the practice of monitoring the amounts and patterns of vibration signals within a component, machinery, or building in order to detect aberrant vibration events and evaluate the overall condition of the test object is known as vibration analysis. Also, Vibration is defined by the dictionary as "a periodic motion of the particles of an elastic body or medium in alternately opposite directions from the position of equilibrium when that equilibrium has been disturbed or the state of being vibrated or in vibratory motion as in (1) oscillation or (2) a quivering or trembling motion." There are various transducers available that can sense vibrational displacement, velocity, or acceleration and generate an electrical output. The optimal unit of measurement for evaluating machine condition will be determined by machine speed and design. Several recommendations have been provided to assist in determining a machine's relative functioning condition. (Sullivan 2010)

Oil analysis

Oil analysis is a routine activity that examines the health of the oil, the contamination of the oil, and the wear of the machine. The goal of an oil analysis program is to ensure that a lubricated equipment is performing as expected. When an anomalous condition or parameter is discovered by oil analysis, urgent action can be taken to remedy the underlying cause or to minimize a developing failure. Oil analysis is performed for obvious reasons, such as understanding the quality of the oil, but it is also designed to assist bring to light the condition of the machine from which the oil sample was collected. Oil analysis is divided into three categories: fluid characteristics, pollution, and wear debris. (Sullivan 2010)

2.1.3.4 Autonomous maintenance

Autonomous Maintenance is a TPM activity that involves operators maintaining their own equipment independently of the maintenance department. Daily inspections, lubrication, part replacement, basic repairs, abnormality detection, and precision checks are all part of an AM program. CLIT stands for cleaning, lubrication, inspection, and tightening. The program's goals are to avoid equipment deterioration, restore equipment to its optimal state, and provide the basic conditions required to keep equipment in good working order. AM is one of the most crucial components of any TPM program. Taylor (2011) defines autonomous maintenance as a technique for involving production workers in equipment care, collaborating with maintenance to stabilize conditions and prevent accelerated deterioration. Taylor (2011) goes on to say that the organization must educate employees about equipment operation and failures, including prevention through early detection and treatment of abnormal circumstances, in order to enhance machine efficiency and increase production outputs.

2.1.4. Performance measurement and machine efficiency

Availability: as the proportion of time that equipment is available or ready for production after all scheduled and unscheduled downtime has been deducted. It should be noted that idle time due to a lack of product demand is not removed from the total time available. The equipment is termed "available" despite the fact that no production is required. Taylor (2011)

$$\text{Availability} = (\text{loading time} - \text{downtime}) / (\text{loading time})$$

The performance rate (P) is calculated by multiplying the operating speed rate by the net operating time. The ratio of standard cycle time to actual cycle time is the operating speed rate.

Quality Rate: - is defined as the proportion of conforming product to total product produced (Campbell, 2006:161).

$$\text{Quality Rate} = (\text{Total Product Produced} - \text{Reject product}) / (\text{Total Product produced})$$

OEE is a way for understanding the performance of a manufacturing region as well as identifying potential constraints (Hansen, 2002). The percentage efficacy of the manufacturing process is calculated using OEE. Furthermore, OEE is a function comprised of three factors: availability, performance efficiency, and quality (Fredriksson and Larsson, 2012).

$$\text{OEE} = \text{Equipment availability (\%)} * \text{Performance Efficiency (\%)} * \text{Rate of Quality (\%)}$$

According to (Subramaniam, 2007), machine efficiency is one of the variables that management commonly overlooks, resulting in losses that lower yield. Improper machine maintenance leads to low standards of manufactured parts and increased machine maintenance. Machines are designed to be efficient, yet in some cases, they can be less productive due to poor preventive maintenance.

Preventive maintenance is critical to keeping the equipment working smoothly throughout the manufacturing process. Machine maintenance requires special attention from management and responsible people to maintain optimum utilization of machineries, which will reduce undesired wastages due to machine stoppages.

$$\text{Machine Efficiency} = \text{Value adding time} / (\text{Value adding time} + \text{Machine Loss time})$$

Where Value adding time VAT = Actual produced / Rated speed of the machine

2.1.5. Challenges of Preventive Maintenance Practices

According to Mobley (2008), preventive maintenance has long been regarded as critical in lowering maintenance costs, improving asset reliability, and increasing production outputs. In practice, it might take many different shapes. The extent of a preventive program should be determined by two important factors: first, the cost of the program in comparison to the carefully measured reduction in overall repair costs and enhanced asset performance; and second, the percentage utilization of the asset being maintained. The argument is weak if the cost of preparing for a preventive-maintenance inspection is essentially the same as the cost of repair after a failure accompanied by preventive inspections.

If, on the other hand, a breakdown could result in significant asset damage and a much more expensive repair, the scheduled inspection time should be taken into account. Furthermore, preventative maintenance in the average plant should be adapted to the function of distinct pieces of equipment rather than being applied uniformly to all equipment. Many other integrated production lines' key pieces of equipment fall into the same category. Periodic examinations of tiny electric motors and power transmissions, on the other hand, can quickly exceed the cost of unit replacement at the time of failure. Indeed, if complete preventative maintenance is impracticable, a program of asset or component replacements can result in much lower maintenance expenses. In a plant with many pumps, for example, a standardization program combined with an inventory of full units of the most commonly used pumps may give a sufficient program for this equipment. This spare-tire mindset can be applied to a variety of other components or subassemblies with positive results. Instead of a centrally administered formal preventative program, qualified technicians are sometimes deployed as mechanical guardians to particular pieces of equipment or groups of equipment. Operating without clerical support and with no documentation, these guys can significantly cut maintenance costs and failures due to familiarity with equipment and the ability to detect mechanical faults in advance (Mobley, 2008). Even in plants where equipment is not in continuous operation and a more thorough preventative program is in place, these compromise devices can frequently be used to greater advantage. Another way of preventing breakdowns and completing maintenance most efficiently is periodic shutdown for comprehensive repair of a whole production unit, similar to the turnaround period in oil refineries.

Taking advantage of a breakdown in some component of the line to perform vital inspections and replacements that can be completed in about the same time as the primary repair is one of the most effective methods of tempering ideal preventive maintenance with practical considerations of a continuous operation. This necessitates documenting flaws discovered during operational inspections and going in immediately with artisans and supervision ready to work until the job is completed. Production management can frequently be persuaded of the need for a few extra hours of labor to repair a breakdown far more easily than they can be persuaded of its necessity when things appear to be running smoothly. (Mobley, 2008).

2.2 Empirical literature review

The research undertaken, “Effective Preventive Maintenance Scheduling: A Case Study” (Hasnida Ab-Samat et. al, 2012), the use of preventative maintenance (PM) has shown that machine failure rates can be significantly decreased, resulting in uninterrupted production. Because of the circumstances involved, most organizations do not always carry out PM on time, which impacts the sole objective of carrying out PM, which demands exact planning on maintenance dates for each machine. However, given the circumstances of the organization, it was clear why the preventative maintenance work could not be completed efficiently. Downtime data and analysis in the case study company revealed a list of critical machines as well as the ineffectiveness of the current maintenance schedule, which does not differentiate between essential and non-critical machines. A further root cause analysis has shown that the machines suffer critical breakdowns when maintenance work is not done properly.

A thesis on the effect of plant and equipment maintenance strategies on factory performance: the case of beverage bottling company, asku plc (mengistu girma,2019) it was primarily intended to discover plant and equipment maintenance procedures used, factors impacting factory performance, and analyzing the relationship between the two, as well as side by side identification of other elements affecting factory performance. According to the findings of the study, maintenance strategies have a favorable link and have a significant impact on factory performance. PM is found to be the most influential factor, followed by breakdown corrective maintenance, with likert scores of 2.8784 and 2.7973, respectively. According to the poll, the most closely observed factory performance indicator and its mean weighted likert score was bottle output per year (3.49), while the least closely monitored was factory time efficiency (2.78). The respondents recognized the impact of plant and equipment maintenance on factory performance indicators, stating that four factory performance metrics were regularly affected by maintenance chores.

The article study on, “Effect of Preventive Maintenance on Machine Reliability in a Beverage Packaging Plant”(Jacob Ben 2021) The influence of preventive maintenance on the reliability of devices in a bottling factory is investigated in this research. Six months of real-time maintenance data were quantitatively analyzed. Mean time between failure (MTBF), mean time to repair

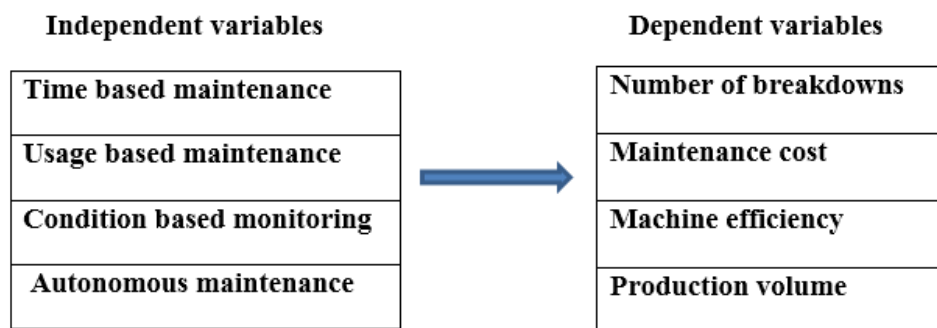
(MTTR), and failure rate for specific equipment are derived based on the breakdown occurrences received for each machine. The bottle packer, empty bottle inspector (EBI), and palletizer have been designated as important machines for the plant. The bottle packer is then subjected to a breakdown analysis (BDA) to determine the failure mode of all recurring problems impacting this equipment as a result of inefficient PM. As part of developing an efficient PM program, an autonomous maintenance (AM) team is formed to increase the reliabilities of essential equipment that were consistently failing. After two months of implementing the AM program, there is a considerable reduction in machine breakdowns. As a result, bottle packer reliability increased from 55.30% to 70.80%, while EBI and palletizer reliability went from 89.20% to 92% and 90.50%, respectively.

2.3 Summary and conceptual frame work

The conceptual frame work helps to clarify the relation between dependent variables and independent variables. Good condition based monitoring maintenance can affect the number of breakdowns occur on a production line and also has effect on maintenance cost with regarding of breakdown works. Time based maintenance projects and autonomous maintenance has a relationship with a production line volume. Performing a well-planned and scheduled usage based maintenance has impact on the line’s machine efficiency after the maintenance is done. In order to test this in EABSC the following hypothesis are proposed.

H1 condition based monitoring maintenance has relation on reducing numbers of breakdowns

H2 usage based maintenance has positive effect on machine efficiency and production volume



Source: (Author, 2023)

CHAPTER III

RESEARCH DESIGN AND METHODOLOGY

3.1. Research Design and Methodology

This study employs a descriptive research design to investigate and assess preventive maintenance on production lines performance on EABSC. According to Miller (1991), descriptive research is the process of collecting data in order to answer questions about the current state of the subject area. According to Saunders (2009), Descriptive research provides an accurate portrait of people, events, or situations. This design provides researchers with a profile of described relevant features of the phenomena of interest from a person, organizational, and industrial standpoint.

Similarly, the researcher strives to obtain an analysis of the relationship between machinery maintenance practices and production performance, first attempting to determine what are the maintenance behaviors of artisans, emotions, and feelings, contexts of organizational functioning, industrial cultural, and interactions among technical and production staff. As a result, for this specific case, a qualitative research approach was used.

On the other hand, the quantitative research approach was very useful in obtaining details on quantitative values of the variables to investigate and cross check the performance of the production lines to determine whether or not it is interconnected and affected by the various maintenance activities performed in the factories. As a result, a mixed research technique is favored since it allows the researcher to collect relevant information in both the production and engineering departments. Thus, the study is empirical in nature and carried out using a cross-section of EABSC manufacturing plants. The research can also be described as a case study because it solely addressed EABSC production lines in Addis.

3.2. Population and sampling technique

3.1.1 Research population

The study included all of EABSC's production lines in Addis Ababa, as well as production, maintenance personnel and Engineering team. The EABSC maintenance staff is structured differently than the manufacturing department. The maintenance team's job is to ensure that the production equipment is always functioning and that failures and related downtimes are resolved and remedied as soon as feasible. Engineering team on the other hand supports the maintenance staff on planning, specialist and spare parts availability. The production lines in EABSC are in two types, The PET line which processes plastic bottled beverages and the RGB lines which produces the glass bottled products. The type of machineries in this lines are different by manufacturer and model types. RGB machineries include Filler, bottle washer, caser, uncaser, blender, crowner, EBI (empty bottle inspection), FBI (Full bottle inspection), date coder machine, different conveyors and create washer. While PET line has machines like Blow moulder, filler, preform feed system, closure feed system, blender, capper, date coder, FBI (full bottle inspection), labeler, shrink wrapper, different types of conveyors, and stretch wrapper machines which are all integrated to achieve a specific production goal using different Simatic and PLC technologies. The focus of research is on machine operators, line technicians, line electricians, mechanical specialists, electrical specialists, maintenance planners, maintenance controllers, and CBM specialist. The study's sample and population units were the four EABSC manufacturing bottling lines in Addis Ababa. A minimum of three respondents from each plant's production and engineering departments were chosen, for a total of 51 respondents.

3.1.2 Sample and Sampling Methods

The study's respondents were chosen using a basic census sampling procedure. Census sampling guarantees that each member of the population has a chance of being chosen in the survey. According to Frank Yates 1960, the census method refers to a statistical examination in which data are collected for each and every element/unit of the population. Selected sample size total of 51 is small and in order to get depth information on the research census sampling method is used.

3.3. Data Collection Tools/Instruments and Types of data

Both primary and secondary data are to be collected. Primary data are gathered to take information on the effect of preventive maintenance projects on production lines performance, challenges on time based preventive maintenance project implementation, usage based maintenance project challenges and its implication on machine efficiency, the benefit of CBM to break down reduction. Secondary data was obtained from the SAP system. All the maintenance costs, maintenance checklists, maintenance efficiencies and production volume are extracted and extrapolated from the SAP system for the last three years.

According to Kothari (2004), the questionnaire method is the best tool for data collection. When compared to alternative ways, it saves time and money. Open and closed ended questionnaires has been used for primary data collection. This questionnaire was prepared in English version and given to the 51 people samples.

3.4. Data collection procedures

The researcher relied on primary data collected via a standard questionnaire, which is delivered by orienting and explaining the aim of the questionnaire to selected respondents with the assistance of respective area maintenance planners. Following that, the respondents were met on-site to provide explanations for the respondents in the event of uncertainty. The study additionally relied on multiple secondary data observations from four production lines that were gathered data for three years SAP report of maintenance and production performances categorized weekly and monthly in order to extract particular information from the data. In addition to that, EABSC CBM annual report is used as secondary data to examine the project relation to breakdown reduction. The surveys are streamlined so that all respondents understand and agree on the meaning of each item.

3.5. Data analysis method

The acquired data was cleaned, entered, and analyzed using IBM SPSS for descriptive statistics, and data from SAP was used to investigate the relationship between usage based maintenance with machine efficiency and production volume. EABSC yearly CBM report is used to support the open ended question which is included in question asking whether CBM reduces break down or not.

3.6. Validity and Reliability

The essence of any research project is its validity and reliability. They are responsible for the accuracy, dependability, and credibility of information. The validity of a study refers to whether the findings are real and certain. The accuracy of your research methodologies and approaches is a component of reliability. The dependability of a study is assessed in quantitative research by confirming the capacity to duplicate the study's results. However, according to Simon (2011), no replication is expected in qualitative research.

Saunders (2003) defines validity as the extent to which a data collecting process or procedures accurately measure what they were designed to measure. A variety of methods were taken to assure the study's validity:

- It is presumed that the data acquired from all targeted groups came from credible sources.
- To verify the validity of the results, questions were posed based on a review of the literature and a frame of reference.

Saunders (2003) defines dependability as the degree to which a data gathering method or procedures will produce consistent results (J. Briony, 2006). SPSS software includes "Reliability Analysis Statistics"; among the reliability models, Alpha (Cronbach) was used in this investigation. Finally, the fundamental distinction between reliability and validity is mostly a question of terminology. Reliability examines the consistency/uniformity/ of your measurement, or, more simply, the degree to which an instrument measures the same way each time it is used in the same settings with the same individuals.

3.7. Ethical Issues

The foundation of research is ethics. It is most visible from data gathering to analysis. As a result, the goal of the paper has been explained impartially during the process of gathering data from the target demographic. Furthermore, the data analysis was carried out without any distortion in its inference.

CHAPTER V

RESULTS AND DISCUSSION

4.1 Characteristics of respondents

Primary data were acquired from 51 respondents who worked in the company's four production lines and had varying educational backgrounds, work experience, and responsibilities. A three years Secondary data on maintenance effectiveness and production volume were taken from the SAP system, analyzed, and interpreted using SPSS software.

4.1.1 Current positions of respondents

In order to maintain the sample variety, sample was taken from people working in different job positions. The below table shows the job positions selected for the survey, the frequency on each job position and their percentage from the total sample. Machine operators, electricians and technicians have participated on the survey form each of the three RGB lines on respective percentage of 25%, 15.7% and 13.7% of the total sample population. Electrical specialists (7.8%) and Mechanical specialist (9.8%) gave responses to the questionnaire from both RGB and PET lines. Maintenance planners and controllers were engaged as a part of the survey as being 7.8% and 5.9% from the survey sample. Whereas, Line process engineers from PET line took 11.8% and CBM specialist taking the 2% to complete the survey samples.

The majority of operators (61%), technicians (85%) and machine specialists (60%) agreed up on that the comments given on the checklists are well addressed by the technical team. Whereas, some operators (37.5%) and line electricians (37.5%) disagreed that their comments lack a certain amount of attention from the technical team.

Table 4.1 Current positions of respondents

Valid group	Frequency	Percent	Valid Percent	Cumulative Percent
Machine operator	13	25.5	25.5	25.5
Line electrician	8	15.7	15.7	41.2
Line technician	7	13.7	13.7	54.9
Electrical specialist	4	7.8	7.8	62.7
Mechanical specialist	5	9.8	9.8	72.5
Line process engineer	6	11.8	11.8	84.3
Maintenance planner	4	7.8	7.8	92.2
Maintenance controller	3	5.9	5.9	98.0
CBM specialist	1	2.0	2.0	100.0
Total	51	100.0	100.0	

Source: (Survey data, 2023)

4.1.2 Respondents work experience

The table below shows the job experience of the employees who took part in the survey. The goal was to find out how long they had been with the company and how much experience they had with maintenance techniques. According to the data acquired, the majority of respondents (49.0%), have worked at EABSC between five to ten years. Whereas, the next highest number is taken by the experience group from two to five years. The experience group from zero to two years (2%) and above 10 years (19.6%) takes the other percentage on the survey sample.

Most of the people on the experience groups of 2-5 years (73%), from 5 – 10 years (80%) and above 10 years (90%) have agreed and strongly agreed that our checklist tasks are easy to understand, clear and understandable to execute. In the other hand, only some of experience groups from 2 – 5 years (26%) and from 5 – 10 years (12%) said that our checklists somehow lack clarity and not understandable to execute.

Table 4.2 respondents work experience

Valid group	Frequency	Percent	Valid Percent	Cumulative Percent
0-2	1	2.0	2.0	2.0
2-5	15	29.4	29.4	31.4
5-10	25	49.0	49.0	80.4
above 10	10	19.6	19.6	100.0
Total	51	100.0	100.0	

Source: (Survey data, 2023)

4.1.3 Educational background of respondents

Educational background information were asked to be answered by respondents. This is due to know the academic/educational qualification of respondents and its relation with preventive maintenance tasks execution problems. The below table illustrates the academic/ educational background of workers who have participated on the survey. Among those, respondents with academic background of technical and vocational school answered that the main challenges of preventive maintenance tasks execution are lack of time given to accomplish PM tasks (31.57%) and lack of tools for operators to do tightening tasks (31.57%). Whereas, respondents with educational level of bachelor degree responded that the main challenges are lack of tools for operators (26.6%) and negligence / lack of concentration to execute checklist tasks (23%). On the other hand, only two respondents where on master degree on academic/ educational background and responded that lack of time (50%) and tool (50%) are the major problems to preventive maintenance task execution.

Table 4.3 Educational background of respondents

Valid group	Frequency	Percent	Valid Percent	Cumulative Percent
Technical and vocational school	19	37.3	37.3	37.3
Bachelor of science / bachelor of art	30	58.8	58.8	96.1
Master of science / Master of art	2	3.9	3.9	100.0
Total	51	100.0	100.0	

Source: (Survey data, 2023)

4.2 Factors affecting line performance

This part is designed to describe the major factors that are there to affect the production line performance according to the respondents. The main aim is to find out how preventive maintenance task execution problem affects the production line performance in the view of the EABSC Addis Ababa plant sample workers. To examine this, one open-ended question was asked on the questionnaire saying “From your point of view, what are the key factors affecting the line performance?” Below table shows the result of the answer by respondents. From the total of 51 respondents, poor preventive maintenance checklist execution has the highest response (25.5%) among the other challenges like machine breakdown, employee motivation, line short stops, raw material quality, and inconsistency in maintenance scheduling and other factors. They also think that good preventive maintenance execution reduces breakdowns which 17.6% effects on the production line performance.

Table 4.4 Major challenges affecting line performance

Major challenges	Frequency	Percent	Valid Percent
poor preventive maintenance checklist execution	13	25.5	25.5
Machine breakdown	9	17.6	17.6
Employee motivation	4	7.8	7.8
line short stops	5	9.8	9.8
Raw material quality	6	11.8	11.8
inconsistent maintenance schedule	9	17.6	17.6
others	5	9.8	9.8
Total	51	100.0	100.0

Source: (Survey data, 2023)

4.3 Challenges on preventive maintenance activities

This was intended to understand the challenges on execution of time-based preventive maintenance activities in EABSC Addis Ababa plant production lines. From the above question, it has been shown that the majority percentage of production line performance challenges were given to poor preventive maintenance checklist execution. Although checklists are in place, but there are breakdowns and performance challenges arise from time-based preventive maintenance execution problems on machine operators and technical

team. On the questionnaire, 13 questions were prepared to evaluate the checklist execution quality and one open ended question asked to respondents that what the major challenges on preventive maintenance execution are. The below table shows the answers of respondents to the questionnaire given to them.

Table 4.5 Summary of respondent answers to time based preventive maintenance practice

Statements	Strongly agree N (%)	agree N (%)	Neutral N (%)	Disagree N (%)	Strongly dis Agree N (%)	Total N (%)
Machine operators and technicians have the awareness on how to execute preventive maintenance checklists.	12(23.5)	27(52.9)	2(3.9)	9(17.6)	1(2.0)	51(100)
Comments written on the checklist get proper feedback and plan from maintenance team.	7(13.7)	27(52.9)	5(9.8)	11(21.6)	1(2.0)	51(100)
Our checklists help us to identify problems at early stages of failure before causing breakdown and improve line performance	24(47.1)	22(43.1)	1(2.0)	4(7.8)	0(0)	51(100)
Checklists are placed in suitable and accessible location for operators and technicians	21(41.2)	25(49.0)	3(5.9)	2(3.9)	0(0)	51(100)
Machine operators and technicians are busy on the line and has no time to execute checklist tasks.	3(5.9)	21(41.2)	2(3.9)	19(37.3)	6(11.8)	51(100)
Check lists tasks are clear and easy understandable to execute	14(27.5)	27(52.9)	3(5.9)	7(13.7)	0(0)	51(100)
Most of the machines on the line has their own checklists	16(31.4)	31(60.8)	2(3.9)	2(3.9)	0(0)	51(100)
Proper cleaning materials and lubricants are provided for cleaning and lubrication tasks	4(7.8)	21(41.2)	8(15.7)	13(25.5)	5(9.8)	51(100)
Machine operators lubricate their machine based on the color coding around the lubrication point.	7(15.9)	14(31.8)	8(18.2)	12(27.3)	3(6.8)	51(100)

Source: (Survey data, 2023)

A total of 47 respondents agreed and strongly agreed on most of the machines on the line has their own checklists saying the overall checklist plan coverage is good and only 3.9 % of respondents have different idea that there are areas that the checklist didn't cover. Respondents said that Machine operators and technicians are not busy on the line and has time to execute checklist tasks are totally 49.1%. Closely, there were 47.1% of respondents answered that they are busy on production process and doing corrective maintenance tasks so that they lack certain time for checklist execution.

Regarding autonomous maintenance perspective, questions were asked whether proper cleaning materials and lubricants are provided for cleaning and lubrication tasks. 49% of respondents agreed that the clearing materials and lubricants are given. Whereas, 35.3% of respondents disagreed that when cleaning and lubrication tasks are held, they didn't get enough cleaning material and lubrications. Also 47.7% of respondents said that machine operators lubricate their machine based on the color coding around the machine lubrication point. But 34.4% of respondents disagreed that the color coding on lubrication point isn't followed when lubrication task is performed.

Open ended question asked to participants to mention the major challenges on time based preventive maintenance practices. The below chart shows the response of participants which lack of time for preventive maintenance tasks, lack of appropriate tool for operators, lack of spare parts, negligence and lack of concentration given to checklists and other reasons.

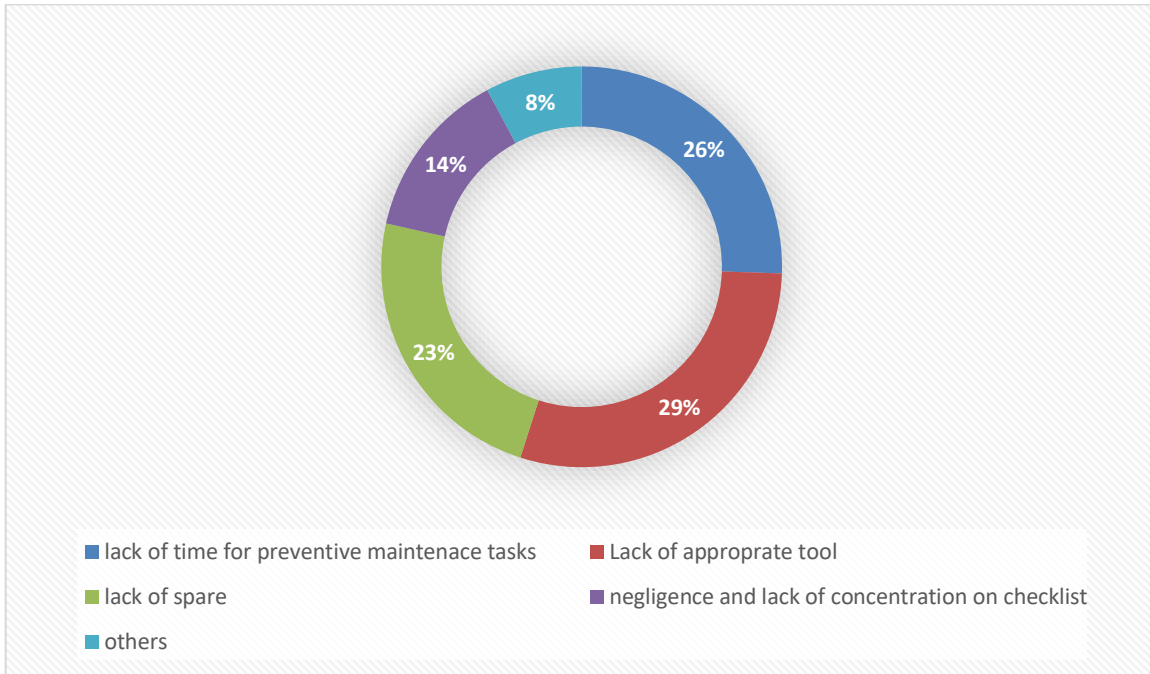


Figure 5 - Preventive maintenance challenges

Source: (Survey data, 2023)

4.4 Usage based maintenance vs. machine efficiency

This part is designed to explain the effect of usage based maintenance project on the machine efficiency of the production lines. To analyze this effect, seven questions and one open ended question asked the participants on the questionnaire. And also a three year data for production volume and machine efficiency values from all three RGB lines were taken to be analyzed how they behave after each year overhaul window. The below table shows the responses given by participants on usage based (overhaul) maintenance challenges and its effect on machine efficiency.

Table 4.6 Summary of respondent answers on usage based maintenance questions

Statements	Strongly agree	Agree	Neutral/ undecided	Disagree	Strongly disagree	Total
Time allocated for shutdown maintenance is enough for completing all scheduled tasks.	4(7.8)	18(35.3)	6(11.8)	16(31.4)	7(13.7)	51(100)
All necessary spares will be available for overhaul maintenance.	3(5.9)	6(11.8)	5(9.8)	21(41.2)	16(31.4)	51(100)
Machine efficiency and production volume won't be improved after overhaul maintenance	3(5.9)	13(25.5)	4(7.8)	22(43.1)	9(17.6)	51(100)
Skipping recommended overhaul maintenance time will affect the line performance	4(7.8)	28(54.9)	6(11.8)	9(17.6)	4(7.8)	51(100)

Source: (Survey data, 2023)

One of the challenges on usage based preventive maintenance projects as per the participants is time allocated for shutdown maintenance. 45.5% of respondents answered that the time given for attaining all usage based maintenance project tasks is not enough. On the other hand, 43.1% of the respondents think that the time given for finishing all tasks on overhaul maintenance is enough. The other factor for successful overhaul is availability of spare parts as per the original equipment manufacturer recommendation. A total of 72.6% of participants agreed on not all necessary spares will be available for shutdown maintenance. Only 17.7 % of respondents think the spares availability during overhaul maintenance is on the amount of needed. As it was discussed on chapter two, usage based maintenance can be done by a certain running hour of machineries. Skipping overhaul window can also affect the line performance. 62.7% of participants agreed on skipping overhaul maintenance will definitely affect the production lines performance. Whereas, 25.4 % of respondents disagreed that skipping shutdown maintenance window has no effect on production lines performance. Machine efficiency and production volume are among the measures of line performance. 60.7% of respondents agreed that machine efficiency and production volume will improve after overhaul maintenance. On the other hand 31.4% of respondents said that machine efficiency and production volume will not be improved after shutdown maintenance.

Usually shutdown maintenances are done during Ethiopian summer time, between July to September. This is due to the cold weather sales volume decreases and giving the maintenance team time for such time taking maintenance project. To explain more about the effect of usage based maintenance on machine efficiency and production volume, a three years of production volume and machine efficiency data were taken from SAP system. Below are graphs on production volume and machine efficiency respectively.

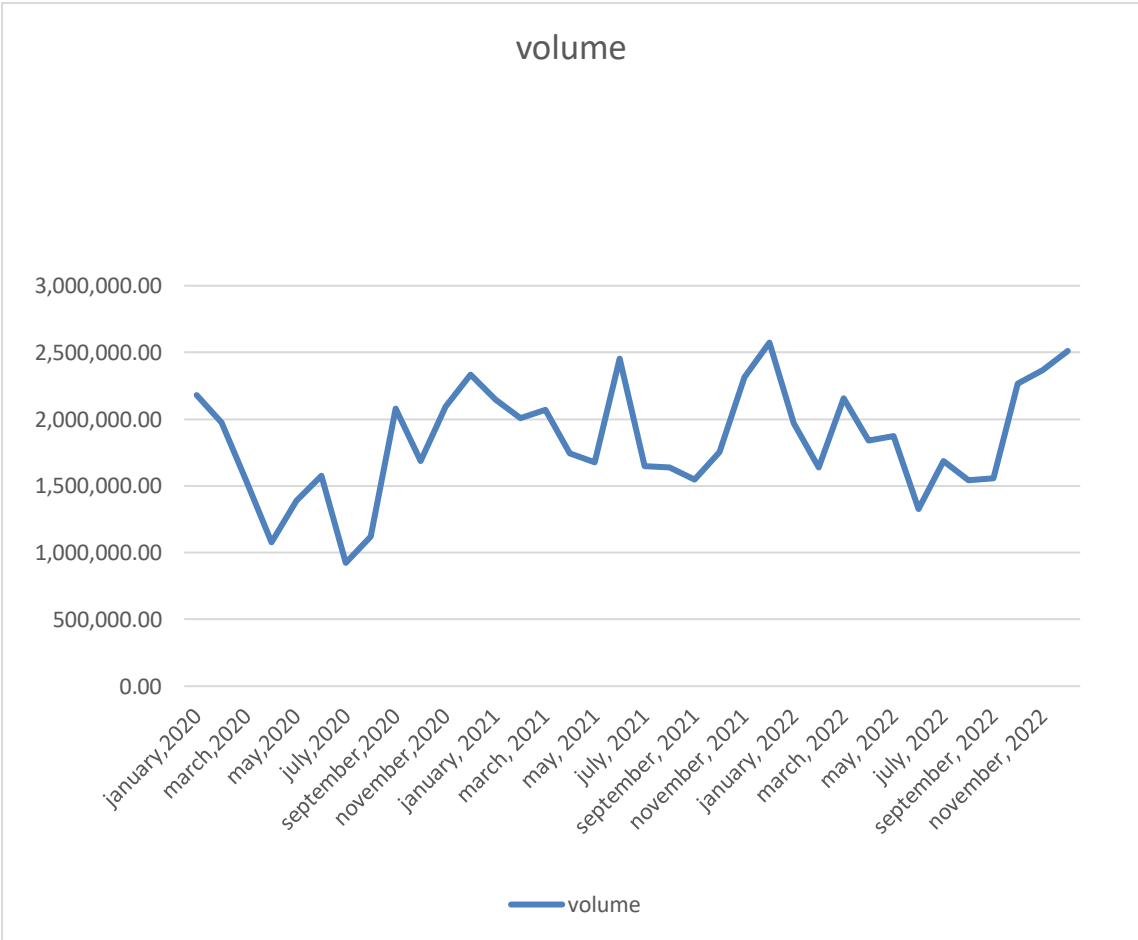


Figure 6 - Production volume data on 2020-2022
 Source: (SAP System, EABSC)

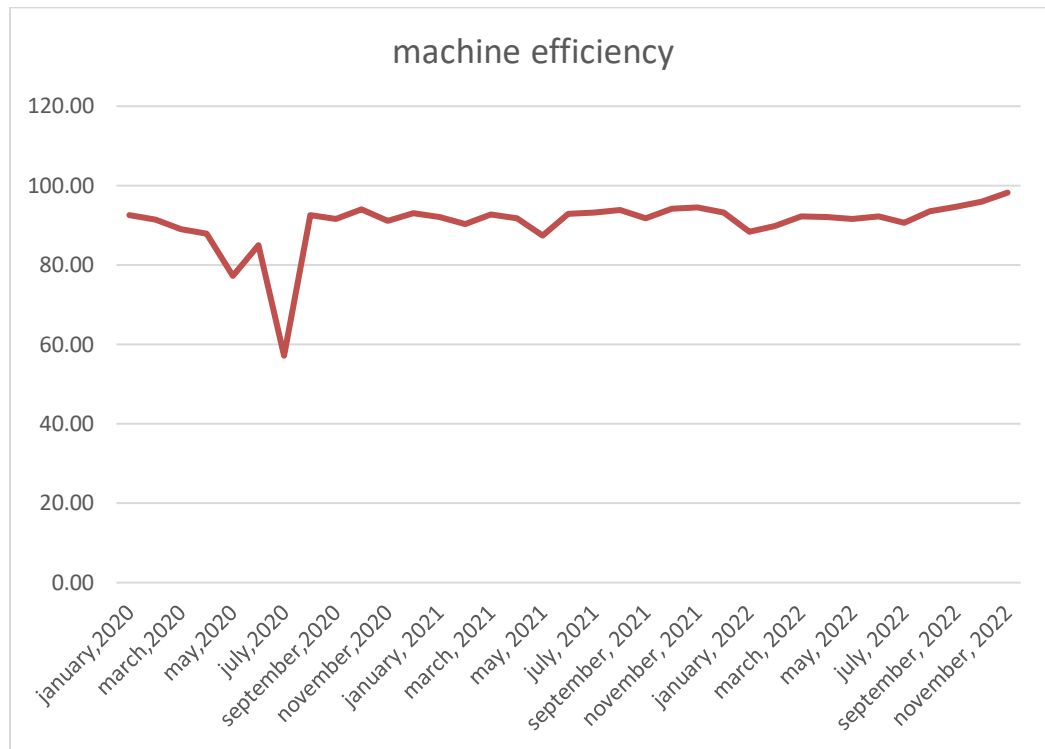


Figure 7 - Machine efficiency form 2020 – 2022

Source: (SAP System, EABSC)

According to SAP, overhaul maintenance was done on July, August and September months on 2020, 2021 and 2022 respectively. During 2020, the average volume before July overhaul window was 1,622,772.6 cases and the average machine efficiency during this period was 87.19%. Whereas, the machine efficiency and production volume were improved after that. The average production volume after overhaul shutdown is 1,862,468.8 and machine efficiency was 92.5%. On the year of 2021, usage based maintenance was in place during August month. The average production volume and machine efficiency are 1,923,855.5 and 91.77% respectively. And after the shutdown maintenance was done line performance progressed to 2,214,787.333 in volume average and 93.9% on efficiency average. The same is true for the year 2022, before shutdown maintenance the lines combined to have the mean volume of 1,785,274.286 and mean machine efficiency to be 91%. After shutdown was done, the line performance improved to 2,175,758 cases average volume and 96.7% mean machine efficiency.

In order to analyze the challenge regarding successful shutdown maintenance, one open end ended question was asked to respondents. The below table shows the respondents answers regarding reasons for time and spare part challenges on overhaul maintenance. 34% of respondents answered that the main reason for lack of spares is budget scares. 29.4% of participants responded that the main issue due to spare challenge is lack of forex and on time delivery problem.

Table 4.7 Summary of respondents answer on reasons for time and spare challenges during overhaul maintenance

Valid group	Frequency	Percent	Valid Percent
no, due to lack of budget	16	31.4	31.4
no, due to lack of maintenance time	14	27.5	27.5
no, due to lack of forex and on time delivery	15	29.4	29.4
others	6	11.8	11.8
Total	51	100.0	100.0

Source: (Survey data, 2023)

4.5 Condition based monitoring maintenance projects

This part is designed for examine the effect of condition based monitoring maintenance projects on breakdown reduction. One open ended question is included in the survey questioner and as a secondary data yearly EABSC CBM report is used. The open ended question asked respondents that does CBM has an effect on machine break down reduction and to explain their answer. The below table gives the response of participants to this survey question. Most of the respondents agreed on CBM has an effect on reducing machine breakdown. Among those, 29.4% of them said it helps to reduce breakdown by identifying problems early before causing breakdown. Also 29.4% of participants agreed on breakdown reduction effect and said CBM reduces cost and increase machine availability. The other 21.6% responded as CBM increases machine lifetime and reduces breakdown rate. The least percentage value with 19.6% gave additional ideas like CBM helps to reduce maintenance by giving opportunity to plan and repair the machine before it caused breakdown.

Table 4.8 Summary of respondents answer on the effect of CBM on breakdown reduction

Valid response	Frequency	Percent	Valid Percent
yes, it identifies problems before breakdown	15	29.4	29.4
Yes, it increases machine lifetime & reduce breakdown rate	11	21.6	21.6
yes, it reduce cost and increase machine availability	15	29.4	29.4
others	10	19.6	19.6
Total	51	100.0	100.0

Source: (Survey data, 2023)

The yearly EABSC CBM report is prepared by CBM specialist including Addis Ababa, Bahir Dar, and Dire Dawa and ambo plants so far. As Sebeta is a new plant it will be included by 2023 year report. To support our idea, we have referred to EABSC CBM report on 2022 to see if there were identified faults and how many breakdowns reduced by this analysis and also by that how much cost is saved. The below figure describes the fault identified on machineries with in the year of 2022. There were 19 machines under high fault needing urgent attention and action to prevent the breakdown from occurring. 35 machines were under low fault needing investigation or corrective action at the earliest maintenance opportunity. Whereas, 43 machines had high alert with a meaning of not urgent but plan repair for the next natural outage. In addition to this 56 machines had low alert with earliest sign component damage indicated and will be monitored in the future.

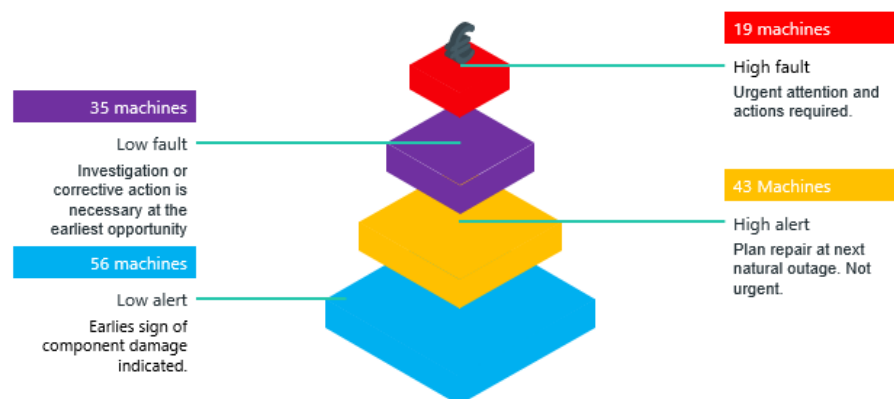


Figure 8 - CBM on reducing machine break down

Source: (EABSC CBM report, 2022)

On the below diagram, it can be seen that through the year of 2022 CBM monitored high faults on different equipment. By planning it early and taking corrective action on time, it reduced machine breakdowns could have occur on different 23 machineries. To put this on cost ways, it is calculated on a situation CBM is not acting and corrective measures had not been taken to high fault machinery conditions and each major findings result a breakdown taking 2hrs of production downtime to be corrected. Under this consideration, CBM maintenance also saved around 36 million birr on the year of 2022.

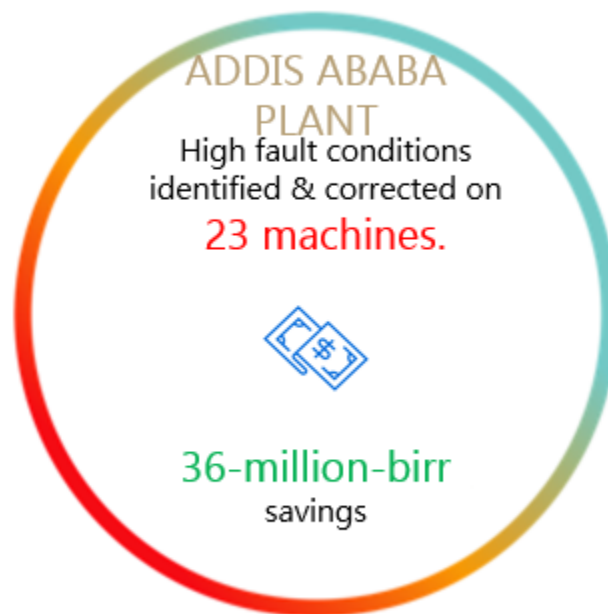


Figure 9 - CBM effect on reducing breakdown rate

Source: (EABSC CBM report, 2022)

CHAPTER IV

CONCLUSION AND RECOMMENDATION

5.1. Summary and Conclusion

The study identified the highest percentage among the factors affecting production lines performance is poor preventive maintenance checklist execution by 25.5%. Among different challenges on time based preventive maintenance projects, this research showed lack of appropriate tools for operators (29%) and lack of time given to finish preventive maintenance tasks (26%) are the major challenges. The other preventive maintenance strategy used in EABSC is usage based preventive maintenance.

This study showed the line performance after this shutdown maintenance is way better than the times before. 60.7% respondents agreed that after overhaul maintenance done, machine efficiency and production volume numbers improved. Three year data taken from SAP system supported this idea by showing the progress in production volume average and machine efficiency average to before overhaul time averages.

CBM maintenance is also another maintenance model in EABSC. The survey showed that 80.4% participants agreed on CBM reduces machine breakdown rate by identifying problems early, by increasing machine life time, by reducing cost and increasing machine availability. Secondary data from EABSC yearly CBM report supported the idea by showing the amount of machineries under monitoring and by corrective action reduced machine breakdowns on 23 machineries and saved 36 million ETB.

In conclusion it can be deducted from the survey to EABSC to improve production lines performance by reducing breakdown rate, giving attention to proper checklist execution and reducing the challenges on preventive maintenance tasks are very mandatory. Machine efficiency and production volume will be improved by not skipping overhaul maintenance window and by availing necessary spare parts to conduct successful shutdown maintenance project with sufficient time to finalize maintenance tasks.

One of the factor affecting line performance is machine breakdown and it can be reduced by implementing CBM maintenance projects on production lines. It can increase machine efficiency and production volume by identifying problems by identifying problems early, by increasing machine life time, by reducing cost and increasing machine availability.

5.2. Recommendation

Taking the research in to consideration, preventive maintenance projects have significant role on overall organizational success as it lays on sales of beverages that are produced by production lines. This lines has different machineries and needs multiple maintenance strategies. Among preventive maintenance is one of it. If so, its benefiter to focus on preventive maintenance projects in order to have production line performances. This study identified gaps to get attention by EABSC that it's better to focus on improving poor checklist execution practice regarding time based preventive maintenance projects so that it can increase life time of machineries and reduce breakdown rate.

Availability of tools for operators is the other point regarding autonomous maintenance helps the operators to execute their tightening tasks better. To improve negligence and lack of concentration on checklist task execution, the company should include it on key performance indicator that evaluates the half yearly based performance and development review. By doing so, better attention and focus will be given by operators and technicians to proper checklist execution. Taking budget and forex issues in to consideration, availing all spares could be difficult but the study showed skipping overhaul maintenance can affect the production line performance.

To avoid that doing on time shutdowns as per the original equipment manufacturer recommendation is recommended to improve machine efficiency and production volume numbers. This research showed that CBM is very essential in reducing machine break downs. It's better to strengthen CBM department by additional equipment and technologies will increase its addressability in all manufacturing of EABSC and can make way better impact on breakdown reduction and cost saving.

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ANNEX-1

Table 4.9 Summary of SPSS analysis to time based preventive maintenance practice

Item-Total Statistics	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Machine operators and technicians have the awareness on how to execute preventive maintenance checklists	29.5294	17.414	.576	.638
Comments written on the checklist get proper feedback and plan from maintenance team	29.7647	16.904	.659	.620
Our checklists help us to identify problems at early stages of failure before causing breakdown and improve line performance	29.0196	20.820	.270	.699
Checklists are placed in suitable and accessible location for operators and technicians	29.0392	20.998	.305	.693
Machine operators and technicians are busy on the line and has no time to execute checklist tasks.	30.3922	19.523	.241	.715
Most of the machines on the line has their own checklists	29.1176	21.746	.222	.705
Proper cleaning materials and lubricants are provided for cleaning and lubrication tasks	30.1961	19.121	.306	.698
Machine operators lubricate their machine based on the color coding around the lubrication point.	30.0784	19.674	.330	.690
Check lists tasks are clear and easy understandable to execute	29.3725	18.238	.559	.646

Reliability Statistics

Cronbach's Alpha	N of Items
.706	9

Source: (Survey data, 2023)

Table 4.10 Summary of respondents answer on preventive maintenance challenges

Valid group	Frequency	Percent	Valid Percent
Lack of time for preventive maintenance tasks	13	25.5	25.5
Lack of appropriate tool	15	29.4	29.4
Lack of spare	12	23.5	23.5
Negligence and lack of concentration on checklist	7	13.7	13.7
Others	4	7.8	7.8
Total	51	100.0	100.0

Source: (Survey data, 2023)

Table 4.11 Summary machine breakdown rate and number of breakdown per production line per year

production line	year	machine breakdown rate	no of breakdown per year
line 1	2020	5.50%	505
	2021	5.60%	616
	2022	4.80%	548
line 3	2020	11.02%	1805
	2021	6.88%	1509
	2022	4.50%	912
line 4	2020	19.49%	1904
	2021	18.74%	2671
	2022	5.22%	710
line 5	2020	10.05%	567
	2021	8.42%	582
	2022	8.39%	627

Source: (SAP System, EABSC)

Table 4.12 Machine breakdown rate and number of breakdown per production line per year

month	volume	ME
January,2020	2,179,730.00	92.53
February,2020	1,975,780.93	91.52
March,2020	1,534,811.00	89.00
April,2020	1,078,381.00	87.85
May,2020	1,391,244.00	77.26
June,2020	1,576,689.00	84.98
July,2020	923,771.00	57.15
August,2020	1,119,990.00	92.59
September,2020	2,080,026.00	91.62
October,2020	1,687,370.00	94.09
November,2020	2,092,454.00	91.19
December,2020	2,332,504.00	93.05
January, 2021	2,146,818.00	92.09
February, 2021	2,009,051.00	90.30
March, 2021	2,071,320.00	92.79
April, 2021	1,744,031.00	91.69
May, 2021	1,675,123.00	87.35
June, 2021	2,453,407.00	92.86
July, 2021	1,650,705.00	93.29
August, 2021	1,640,389.00	93.85
September, 2021	1,546,864.00	91.80
October, 2021	1,754,099.00	94.17
November, 2021	2,316,157.00	94.54
December, 2021	2,574,106.00	93.27
January, 2022	1,971,402.00	88.38
February, 2022	1,639,966.00	89.77
March, 2022	2,157,675.00	92.30
April, 2022	1,838,782.00	92.15

May, 2022	1,874,251.00	91.60
June, 2022	1,327,170.00	92.26
July, 2022	1,687,674.00	90.57
August, 2022	1,545,151.00	93.51
September, 2022	1,555,866.00	94.73
October, 2022	2,267,829.00	95.97
November, 2022	2,366,115.00	98.24
December, 2022	2,513,222.00	98.02

Source: (SAP System, EABSC)

Appendix I – questionnaire

Questionnaire to be filled in by Employees

Dear Respondents,

I am working my research on “**The effect of Preventive Maintenance project on production lines performance: the case of East Africa Bottling share company Addis Ababa Plant**”; as a partial fulfillment of Master of Art Degree in Project Management in Addis Ababa University. So, I kindly demand your support by responding to the below survey with your honest and sincere feedback.

Thanks in advance for your kind support!

Robel Wolde

Section A: General information

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

1. What is your current position in the company?

.....

Line technician Line electrician Mechanical specialist
Electrical specialist Line process Engineer Production Team leader
Maintenance Controller Maintenance Planner CBM specialist

2. Gender: Female male

3. Work experience in the company in the current position:

0 – 2years 2 – 5 years 5 – 10 years above 10 years

4. Level of education:

High school graduate Technical & vocational school

Bachelor of Science/Bachelor of Art Master of Science/Master of Art

Part I: Effect of preventive maintenance on production line performance

Instruction: Hence, you are kindly requested to tick (√) the most appropriate response for each of the question statements found under each part in the table below with the following scores in mind. **5- Strongly agree, 4- agree, 3- neutral/Undecided, 2-disagree, 1-Strongly disagree.**

Section 1: challenges on preventive maintenance activities		strongly agree	agree	neutral/ undecided	disagree	strongly disagree
I.	Machine operators and technicians have the awareness on how to execute preventive maintenance checklists.					
II.	Comments written on the checklist get proper feedback and plan from maintenance team.					
III.	Machine operators and technicians do not fill their checklist without checking the attachment and executing the task.					
IV.	Our checklists help us to identify problems at early stages of failure before causing breakdown and improve line performance					
V.	Checklists are placed in suitable and accessible location for operators and technicians					
VI.	Machine operators and technicians are busy on the line and has no time to execute checklist tasks.					
VII.	Operators and technicians are negligent on checklist execution.					
VIII.	Check lists tasks are clear and easy understandable to execute					
IX.	Most of the machines on the line has their own checklists					
X.	Management interrupt cleaning, inspection, lubrication and tightening tasks to start production early					
XI.	Proper cleaning materials and lubricants are provided for cleaning and lubrication tasks					
XII.	Machine operators has easy access to tools needed for tightening tasks.					
XIII.	Machine operators lubricate their machine based on the color coding around the lubrication point.					
Section 2: usage based (overhaul / shutdown) maintenance						
I.	Time allocated for shutdown maintenance is enough for completing all scheduled tasks.					
II.	All necessary spares will be available for overhaul maintenance.					
III.	We won't pass overhaul window for every machine.					
IV.	Machine efficiency and production volume won't be improved after overhaul maintenance					
V.	Skipping recommended overhaul maintenance time will affect the line performance					
VI.	Requested budget will be allocated to avail all requested spares for overhaul maintenance.					
VII.	I know the overhaul (shutdown) maintenance cost I did					
Section 3: predictive (CBM) maintenance						
I.	Machine operators and technicians have awareness about condition based monitoring (CBM maintenance) in Addis Ababa plant					

II.	We don't need a maintenance strategy for predicting failure on the line					
III.	Condition based monitoring reduces breakdown on the line					
IV.	I have at least observed or participated on Ultrasound monitoring, Vibration monitoring, Infrared thermography or Oil analysis of CBM activity.					

Part II. Open ended questions:

Dear participant, you are allowed to provide valuable and relevant information to each of the questions

1. From your point of view, what are the key factors affecting the line performance?

2. What do you believe to be the main challenges on preventive maintenance tasks execution?

3. Do you believe there is enough time and spares given for proper overhaul maintenance? Why?

4. Does predictive maintenance (CBM) has an effect on machine breakdown reduction? Explain how?

