Investigation of Maintenance strategy to words profit maximization

A case study in Ethiopian Shipping & Logistics Services Enterprise

Kality in Land Transport Branch

ESLSE

Kebebe Urgie Bedasa

A Thesis Submitted to the department of Mechanical Engineering

School of Mechanical, Chemical and Materials Engineering

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Mechanical Engineering (Specialization in Manufacturing Engineering)

Office of Graduate Studies

Adama Science and Technology University

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Declaration

I hereby declare that this Master Thesis entitled Investigation of Maintenance strategy to words profit maximization" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation

Kebebe Urgie		
Name of the student	Signature	Date

Recommendation

I/we, the advisor(s) of this thesis, hereby certify that I/we have read the revised version of the thesis entitled “Investigation of Maintenance strategy to words profit maximization” prepared under my/our guidance by Kebebe Urgie submitted in partial fulfillment of the requirements for the degree of Master of Science in manufacturing Engineering. Therefore, I/we recommend the submission of revised version of the thesis to the department following the applicable procedures.

Dr. Moera Gutu_____ _____ _____

Advisor Signature Date

Approval Sheet

I/we, the advisors of the thesis entitled “Investigation of Maintenance strategy to words profit maximization” and developed by Kebebe Urgie, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Dr. Moera Gutu_____ _____ _____

Advisor Signature Date

We, the undersigned, members of the Board of Examiners of the thesis by -- Kebebe Urgie have read and evaluated the thesis entitled “Investigation of Maintenance strategy to words profit maximization” and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in manufacturing Engineering.

_____ _____ _____

Chairperson Signature Date

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Internal Examiner Signature Date

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External Examiner Signature Date

Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

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Department Head Signature Date

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School Dean Signature Date

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Office of Postgraduate Studies, Dean Signature Date

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Acronyms and Abbreviations

BSC	Balance score card
CBM	Condition-based maintenance
CMMS	Computerized maintenance management System
FMEA	Failure Modes and Effects Analysis
FTA	Fault Tree Analysis
GCMMS	Garage Computerized Maintenance Management System
HSE	Health, Safety and environment
KPI	Key Performance Indicator
MMIS	Maintenance Model Integration System
MMT	Maintenance management tool
MPM	Maintenance Performance Measurement
OEEE	Overall Environmental Equipment Effectiveness
PdM	Predictive maintenance
QFD	Quality function deployment
RCA	Root Cause Analysis
RCM	Reliability-centered maintenance
RPN	Risk Priority Number
TPM	Total Productive Maintenance
TQM	Total quality management
VDM	Value-driven maintenance
VDM	Value-driven maintenance
WO	Work Order

Abstract

Maintenance is the combination of all technical, administrative and timely actions the life cycle of the object intended to maintain, today many industries in our country are facing a crisis of asset processing that leads to lower production, Ethiopian Shipping & Logistics Services Enterprise Kality in Land Transport Branch was one of the industries that facing crisis. The main purpose of this thesis was investigation of maintenance strategy to words profit maximization by addressing the root causes of fragmentation and developing the CMMS software with developing maintenance management framework in the case company, both the quantitative and qualitative data required for the survey were collected from the company. the data obtained from the respondents were to a systematic questionnaire distributed by a sample of 67 respondents taken from the Department of Maintenance management staff and the downtime truck data were obtained from the company's annual report. The data collected was analyzed by analytics tools, namely Microsoft Excel and SPSS analysis and the proposed solution was provided to improve company productivity. This analysis identified the key area facing the downtime in company, maintenance under road call repair and maintenance under body was a critical area of downtime resulted in loss of production for truck drivers. The CMMS concept and maintenance management framework was developed for the trial company in this study, the new concept framework discusses both the theoretical and practical areas identified in this study and developed software (KalityGCMMS) which was used to collect data for all work in the company workshop. Verification was done by presenting research to technical staff and managers to obtain their expert opinion and find it appropriate, The Research can also be used as part of new research in this area.

Keywords: *Computerized maintenance management systems, CMMS, maintenance management Framework, maintenance, maintenance management.*

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CHAPTER -1

1. Introduction

1.1 Background of the Study

Er-ratby and Mabrouki 2018, manufacturing industry has experienced an unprecedented degree of change in the last three decades, involving drastic changes in management approaches, product and process technologies, customer expectations, supplier attitudes as well as competitive behavior, in today's rapidly changing marketplace, slow and steady improvements in manufacturing operations do not guarantee sustained profitability or organizational survival. thus, the organizations need to improve at a faster rate than their competitors if they are to become or remain leaders in the industry(Ismail and Kamal 2020). Bakri et al., 2020 shows that in recent years, industry managers have been gradually moving to the idea that maintenance can be a profit generating function rather than merely a cost center. when it comes to issues such as reliability, availability, safety, quality and cost-effectiveness of equipment and facilities, there is no doubt that maintenance costs can be high and often representing a significant portion of recurrent budgets(Fraser and Tseng 2015).

1.2. Problem Statement

On literature an increasingly number of companies replace the current reactive, “fire-fighting” maintenance strategy with proactive strategies(Gackowiec, 2019), (Franciosi et al., 2018a), (Nijhof and Andre HJ Jeurissen, 2017). This is also the current maintenance practice in ESLSE Kallity branch which hinders the company from not achieving its targets.

Table 1.1: Production(trip) Truck performance

Year	Plan to be produced(tripped)	Actual produced (tripped)	Trip Performance in %	Total Maintenance Down Time Days	Total Operational Downtime in Day	Total Days
2011	3.54	2.7	76.2	9145	776	88695
2012	3.2	2.6	81.2	8154	865	75190
2013	2.75	2.4	87.2	7231	668	68620

The company data indicates that the average track production performance of the past three years is around 81.5 %. The main reasons that hinder the company not to achieve the target are Maintenance down time and valid other stoppages.

- Valid other stoppages are downtimes due to lack of quality spare parts, political instability, unplanned insurance operation, and other factors that cannot be avoided or beyond by management.
- Operational downtime can be caused by Truck breakdowns or operational problems. This also includes human resource related issues such as operating trucks at maximum speed by drivers so as to get incentives, under staffed maintenance team, commitment of maintenance staff to perform routine and non-routine inspections periodically and high turnover of truck drivers.

This indicates that there is a maintenance problem in the company, in addition to normal wear and deterioration, other failures may occur especially when the equipment are pushed beyond their design limits or due to operational errors.

Therefore, this study addresses the maintenance problem by investigate maintenance strategy of the company in order to increase profit maximization of the company.

1.3. Basic Research Question

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

The questions include:

1. What is the present maintenance system in ESLSE?
2. What are the major problems in the current maintenance system on ESLSE?
3. What are the causes of poor maintenance in the ESLSE?
4. How to improve the existing maintenance problems of ESLSE?

1.4. Objectives

1.4.1. General objective

The main objective of this thesis is to Investigate Maintenance strategy to words profit maximization by addressing the root causes of breakdowns and developing maintenance management framework with CMMS software in Ethiopian Shipping & Logistics Services Enterprise Kality in Land Transport Branch.

1.4.2. specific objectives

The specific objectives of this research are:

1. To evaluate company maintenance performance, maintenance culture and challenges.

2. Developing maintenance management system (maintenance management framework) based on the existing models.
3. To transfer all manual controlling maintenance management activities to computerized maintenance management system or (CMMS) software that centralizes maintenance information and facilitates the processes of maintenance operations**.**

1.5. Significance of the study

The main aim of Truck maintenance is to maintain the functionality of the Trucks and to minimize its breakdowns. for mechanical equipment, the maintenance management will involve repair, replacement, and serving of tools. It also ensures the proper working and to intercept fluctuations that occur in the duration of the production process.

The fact remains that, any kind of change even a minor downtime could reduce the overall efficiency of Trucks which would lead to major production losses. Therefore, it is important for organizations today to get and implement a good maintenance management strategy with the best Framework including computerized maintenance management system. Without or in the absence of equipment management, it might be possible to face some consequences in revert of careless decisions.

1.6. Scope of the thesis work

Research focuses on case company maintenance management system and any maintenance related issues.

1.7. Expected Results from the study

The main expected result from this paper is: -

- Identified existing maintenance management gaps.
- A newly developed maintenance management system software and maintenance management Framework for Ethiopian Shipping and Logistics Service Enterprise.

1.8. Organization of the Study

The thesis has four chapters, The first chapter is about the introduction of the study and Contains background of the study, statement of the problem, significance of the study and scope of the study. The second chapter is an intensive literature review from various sources on the

concept of maintenance at the global and African level, maintenance triggers, strategies, performance indicators, maintenance management frameworks.

The third chapter is the research methodology. In this chapter Data collection and presentation methods, data analysis tools, sampling, sampling techniques and methodological framework presented in detail, primary data collected from various sources through observation, interviews and questionnaires properly integrated and presented in a descriptive manner according to the objective of the study. The fourth chapter deals with results and discussions, data analyzed using overall device efficiency analysis, cause and effect diagram, and various statistical tools. Within this chapter, the maintenance management system for the case company and its implementation procedure will be developed. conclusion, recommendations and references are described correctly. Attachments that contain the necessary information related to the work are attached at the end of this post.

CHAPTER - 2

2. Literature Review

2.1. Definition of terms

Maintenance is a function that must be perform under normally adverse circumstances and stress, and its main objective is to rapidly restore the equipment to its operational readiness state using available resources(Falorca, 2019). Maintenance is combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function(Choudhary, 2016)(Talamo and Rota 2019).

According to John Dixon, without understanding the maintenance management process and establishing a sound maintenance strategy, no improvement effort will have an impact on profitability of the industry. “Maintenance management is important to all business sectors-and critical to those that are capital intensive.” - John Dixon(Consulting and Paper, 2018).

Corporate maintenance systems should reflect the level of cooperation with partners in the supply chains. If the enterprise deepens cooperation with suppliers and customers, it will probably affect the method to manage the production equipment maintenance (Bransk, and Pat 2016). maintenance is an important factor in quality assurance and in some cases determines the long-term success of a company, Poorly maintained resources can cause instability and partially or completely pause the production(Puķite and Geipele, 2017). Malfunctioning machines or complete breakdowns can become a costly process for most companies. When breakdowns occur the labor cost per unit rises as time passes until the machines again run as normal(Bakri et al., 2020).

Any unplanned downtime of machinery equipment or devices would degrade or interrupt a company’s core business, potentially resulting in significant penalties and unmeasurable reputation loss(Ran et al., 2019). as Maletic, Al-najjar and Gomiscek, Effective maintenance aims to enhance company’s profitability and competitiveness through continuous cost-effective improvement of production process efficiency, effectiveness and productivity, which can be achieved via maintaining and improving the quality of all the elements contribute in the production process continuously and cost-effectively (Maletic, 2014)(Al-najjar and Gomiscek, 2014).

All management activities that determine maintenance objectives, strategies and responsibilities to carry them out through, such as maintenance planning, planning and control methods in the organization. including economic (Choudhary, 2016), according to (Oluwatoyin and Olotuah, 2015), All the activities of the management that determine the maintenance objectives or priorities (defined as targets assigned and accepted by the management and maintenance department), strategies defined as a management method in order to achieve maintenance objectives and responsibilities to implement them by means such as maintenance planning, maintenance control, supervision and several improving methods with including economical aspects in the organization.

Maintenance was forgotten during years in detriment of more visible organizational functions such as production or logistics, since for many companies it is considered a function without value (Lopes et al., 2016). Therefore, performance of the maintenance process is critical for the long-term value creation and economic viability of many industries, it is important that the performance of the maintenance process be measured, so that it can be controlled and monitored for taking appropriate and corrective actions to minimize and mitigate risks in the area of safety, meet societal responsibilities and enhance the effectiveness and efficiency of the asset maintained (Shihundla and Adenuga 2019) according to Nijhof, Andre HJ Jeurissen Knowledge is a central component to predictive maintenance which is often referred to as a condition-based imminent maintenance. At this level, diagnostic equipment is used to measure the physical condition of equipment such as temperature, vibration, noise, lubrication, and corrosion(Nijhof Jeurissen 2017).

The main idea behind condition-based maintenance (CBM) is to use degradation information detected from on-line physical equipment sensing techniques and measures to minimize system downtime by balancing the risk of failure and achievable profits. (Fernández del Amo et al., 2018) and Mkalaf says the majority of organizations that apply TPM or RCM gain the benefit of a reduction in machinery failure. This is because technical infrastructure is maintained in a proper condition which promotes production continuity. There is also a sizeable reduction in machine maintenance costs(Mkalaf, 2016). Maintenance management requires the adoption of a basic systems approach, i.e., the implementation of company goals to management goals as well as-known maintenance management philosophies (TPM, RCM, RBI) applied to improve processes often remain only on the basis of service implementation without the need full

integration into existing management systems.(Pacaiova and Glatz, 2015).Computerized Maintenance Management System (CMMS) to plan, schedule and execute these activities. A standardized process to Identify, Plan, Schedule, Execute and Close (IPSEC) will help streamline the transition process (Palakodeti, 2019). Maintenance performance measurement is defined as the multidisciplinary process of measuring and justifying the value created by maintenance investment, and taking care of the organization's stockholders' requirements viewed strategically from the overall business perspective(Er-ratby and Mabrouki, 2018).

A common occurrence when reviewing literature is the fact that authors use an array of terms and words to describe the same or similar concept. The study of maintenance management is no different with terms such as: maintenance models; maintenance methods; maintenance techniques; maintenance systems; maintenance types; maintenance philosophies; and maintenance strategies regularly used Maintenance management models throughout the literature to describe the same notion on maintenance(Hvolb and Tseng 2015).

2.2. Maintenance concept globally

Falorca 2019, Due to the increasing technical advancements, the stimulus of productivity and quality is moving from man to machine. Productivity and quality may be increased only by implementing well developed and organized maintenance system Maintenance is normally perceived to have a poorer rate of return than any other major budget item. Yet, most companies can reduce maintenance costs by at least one-third, and improve the level of productivity, by giving maintenance the management priority it requires. That priority must span all levels of an organization's management structure to develop an understanding at each level of the significance maintenance can have upon the success or failure of organization objective (Oluwatobi et al., 2019)(Ismai and Kamal 2020) but according to Trojan, in Europe, Traditionally, maintenance is sorted and performed by time-based fixed intervals, and it is called preventive maintenance, or by corrective maintenance after breakdown (Trojan, 2018).

In 21st century new thinking and new strategies will be required to realize potential benefits and turn them into profitability. All in all, profitable operations will be the ones that have employed modern thinking to evolve an equipment management strategy that takes effective advantage of new information, technology, and methods(Er-ratby and Mabrouki, 2018).

The economic downturn and the dynamic business environment drive companies to seek more efficient and effective maintenance. Thus, the increasing competition in the market creates a need to search new ways in which companies can differentiate themselves and gain more profit and better competitive position(Alsyouf, 2017).

Hwang and Samat 2019, Maintenance has two parts, an engineering and management part, the engineering part of maintenance is all about to improve maintenance operations, reduce the amount and frequency of maintenance, reduce the effect of complexity, reduce the required maintenance skills, reduce the amount of supply support, determine the optimal frequency and extent of preventive maintenance to be performed, improve and ensure maximum utilization of maintenance equipment, and improve maintenance organization.

On the other hand, the management part talks about all management activities that determine maintenance goals or priorities (defined as goals assigned and accepted by the management and maintenance department), strategy defined as a management method to achieve maintenance goals and responsibilities and carry them out by means such as maintenance planning, maintenance control and supervision, and several improving methods including economical aspects in the organization the function of providing policy guidance for maintenance activities, in addition to exercising technical and management control of maintenance programs(Er-ratby and Mabrouki, 2018).

Literatures show that maintenance management is very important for the performance of the company (Fonseca et al., 2017).

Table 2.1: Emerging trends in maintenance

Attribute	**Earlier**	**Emerging**
Manpower	Simple	Mechanization-Automation Globalizations (crossing boundaries)
Attitude towards maintenance	Necessary evil	Technical matter–profit contributor– partnership
Maintenance strategy	CM-PM-RCM-TPM	Integration of various approaches, e.g., ECM, SMM, etc.
Maintenance optimization models(quantitative)	Mathematical discipline with limited applications	Application oriented, integration with qualitative approaches

Maintenance outsourcing	Not existed	Part of vertical contracting
Maintenance scheduling	Models in isolation	Integration with MMIS
Performance indicators	Reference numbers, surveys, indicators, models –Hibi and Luck	Maintenance management tool (MMT)model
Performance measurement approaches	Value based approach, systems audit approach, data envelopment analysis (DEA)	Balance score card (BSC)approach, Quality function deployment (QFD)
PMS integration within formation system	Poor	Developing
Data collection in measurement of OEE	Not sufficiently treated	Designing of data collection system
Evolution of MMIS	Main frame applications and mostly administration oriented	Evolution in middle ware software (e.g., communication between corporate and plant floor), workgroup computing, integrated system technology, inter enterprise technology.
Spare parts management	Inventory administration	Graphical user interface (GUI)– maintenance management information systems (MMIS).
New maintenance policies	Techniques in isolation	Maintenance strategy in MRP system, Joint implementation of TQM, JIT

Maintenance management frameworks and related tools and techniques are reviewed for this paper and the details are found on maintenance management section.

2.3. Maintenance in Africa

Only few literatures can be discovered in Africa level this shows that more emphasis needs to be given on maintenance area. Revealed literatures are more on evaluation of maintenance management system, improving quality and productivity through maintenance management system. A total of four thesis and four articles reviewed.

Table 2.2: Prepared paper on Maintenance Area in Africa

No	Title of paper	Type of paper	Year	Area
1	Integrating Lean and Green Paradigms in Maintenance Management (South Africa)	Journal	2017	Maintenance management
2.	Total Productive Maintenance A Case Study in Manufacturing Industry (Ethiopia)	Journal	2012	Maintenance management
3	Medical devices in Sub-Saharan Africa: optimal assistance via a computerized maintenance management system (CMMS)	Journal	2019	Maintenance management
4	Prospects of Maintenance Management Functions in Sugar Industries: A Case Study on Ethiopian Metehara Sugar Factory	Thesis	2015	Maintenance management

2.4. Basic Maintenance philosophies

2.4.1. Maintenance triggers

When maintenance triggers occur, it indicates that maintenance must be performed at an operational level. Maintenance triggers are used to alert a technician that maintenance is required. When maintenance triggers are received the operational requirements for the maintenance can be planned, acted upon, and recorded using a CMMS or manual datasheet.

There are five main maintenance triggers: breakdown, time-based, event-based, usage-based, and condition-based(Nuratirah and Salmiah, 2018) and (Bakri et al., 2020)

- **Breakdown trigger:** Breakdown maintenance triggers are initiated when a piece of equipment breaks down into an unusable state, for these maintenance triggers maintenance is required to return the device to service and the failure trigger is the only maintenance trigger used when the maintenance strategy has not been designed at the tactical or strategic level. If the equipment maintenance plan has been specified as a run-to-failure strategy, then the failure trigger is only trigger used for maintenance of that machine. In this case, maintenance, even if unscheduled, remains scheduled maintenance. When a facility has a preventive maintenance strategy, failure trigger initiates maintenance that is both unscheduled and unscheduled.
- **Usage Trigger:** A common example of a usage trigger for maintenance is the schedule suggested by car manufacturers. For example, a car manufacturer may suggest maintenance every 10,000 km. This type of maintenance is triggered through recorded meter data. Other examples include usage based on hours of use and number of production cycles.
- **Condition Trigger:** A condition-based trigger for maintenance occurs after the condition of the equipment has been assessed and consequently determined to be unsatisfactory for continued use without maintenance being planned. Various techniques can be used to assess the condition of a machine, ranging from inexpensive methods such as visual inspection through to more technically demanding techniques such as vibration monitoring and thermographic analysis. Condition is the most complex trigger for maintenance. This is because data about condition must be obtained and interpreted. Often the equipment required to perform condition monitoring requires specialized training and experience to operate effectively. After the data is analyzed, it may indicate that maintenance is required.
- **Time Trigger:** Time is used frequently as a trigger for maintenance activities. With a time, trigger, maintenance is triggered whenever the calendar rolls over to a pre-specified date.

Because the calendar is so easily predicted, time is the least complex trigger to schedule planned maintenance. Time can be used as a trigger in many ways. It can be used to trigger maintenance on regular intervals, say every 6 weeks. It can also be used to trigger maintenance based on the seasons, such as "change air conditioner filters before summer".

- **Event Trigger:** When maintenance is needed due to an external event, an event trigger can be used. For example, a building may need to trigger a series of maintenance tasks if the basement floods, these tasks may include electrical checks, cleaning and boiler checks.

Table 2.3: classification of maintenance type based on maintenance triggers(Alsyouf, 2017)

S. No.	Maintenance trigger	Maintenance type
1.	Breakdown	Run to failure, corrective and preventive
2.	Usage	Preventive, Condition based and Predictive
3.	Condition	Condition based and Predictive
4.	Time	Preventive, Condition based and Predictive
5.	Event	Preventive Condition based and Predictive

2.4.2. Maintenance strategies

According to (Eindhoven and Version, 2021) it is convenient to think of equipment as a collection of interrelated parts & Maintenance operations consist largely (but not solely) in replacing parts of equipment. There are many different approaches that can mix and match, depending on the type of assets, industry, and the size and experience of the maintenance team.

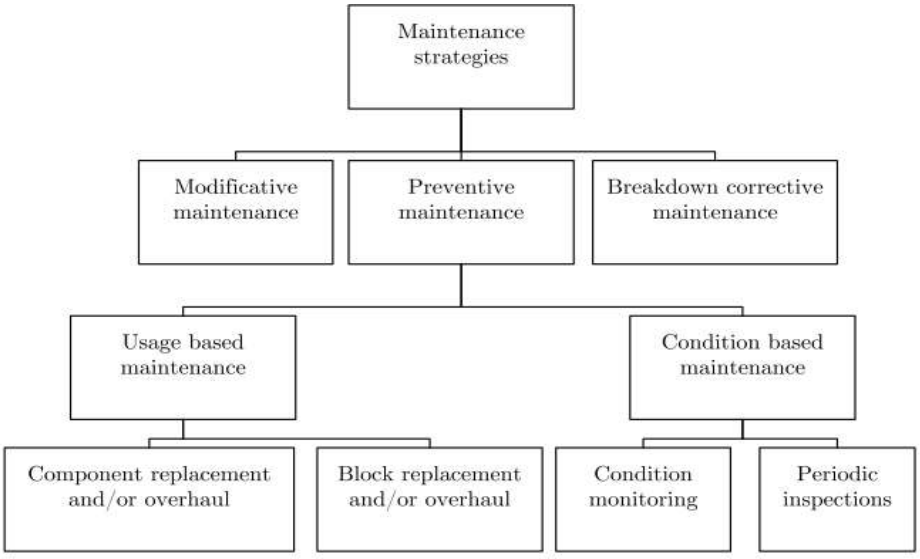

Figure 2.1. Maintenance strategies

Preventive maintenance

Management system of an organization that is responsible for building maintenance gives guidelines for technicians and electricians what to do, when to do and most importantly how to do maintenance works(Munyensanga et al., 2018). On preventive maintenance strategy equipment's needs to be inspected periodically, lubricate, cleaned, calibrated, tested all electrical and mechanical parts are fully functional and replaced any damaged parts so as to run the equipment in a good condition.

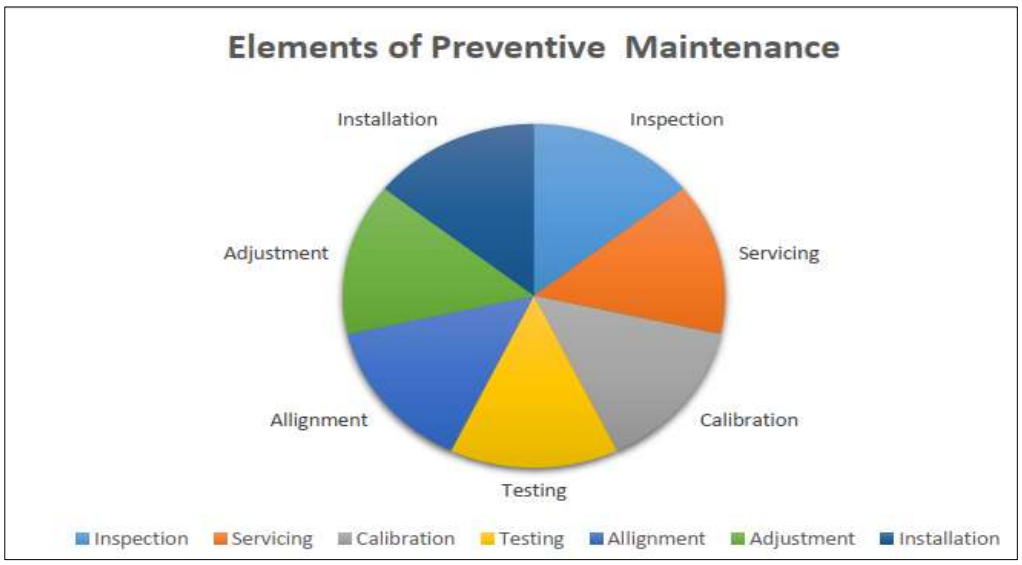

Figure 2.2.Elements of Preventive Maintenance. (Carpitella et al., 2020)(Mohamed and Khodeir 2019)

Reactive maintenance (breakdown maintenance)

Reactive maintenance is pretty simple: fix things when they break. Since repairs are not planned, it's a good method to employ for equipment that is not essential for operations or has a low cost think anything that's rarely used or duplicates the function of other equipment (Fonseca et al., 2017).

Predictive maintenance (PdM)

Predictive maintenance (PdM) aims to predict failures before they happen so maintenance can occur at just the right time. PdM uses data from machine sensors and smart technology to alert the maintenance team when a piece of equipment is at risk of failing. For example, a sensor may use vibration analysis to alert the maintenance team that a piece of equipment is at risk of failing, at which point it will be taken offline, inspected, and repaired accordingly(Olesen and Shaker, 2020).

Reliability-centered maintenance (RCM)

Reliability-centered maintenance (RCM) addresses the fact that failure is not always linear. RCM is a highly-involved process that seeks to analyze all the possible failure modes for each piece of equipment and customize a maintenance plan for each individual machine. The ultimate goal of RCM is to increase equipment availability or reliability(Singgih et al., 2019).

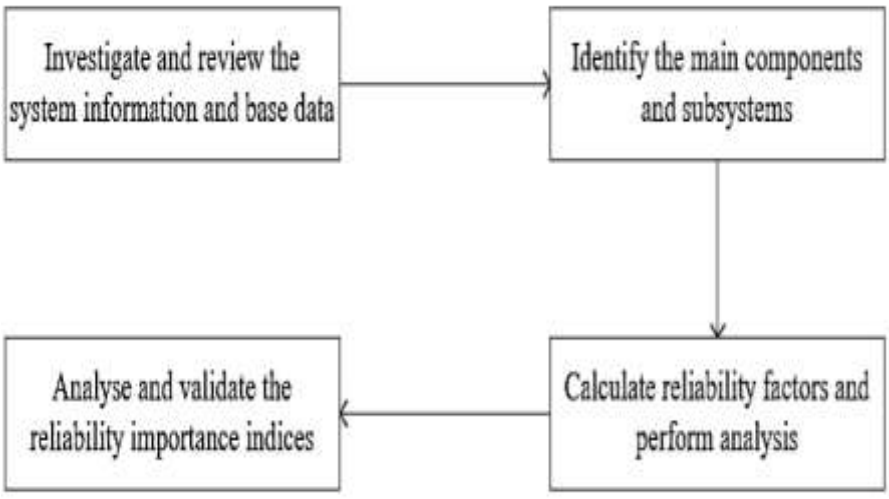

Figure 2.3. Work flow of reliability analysis (Ismail et al., 2020)

Risk-based maintenance

Risk-based maintenance (RBM) prioritizes maintenance resources toward assets that carry the most risk if they were to fail. It is a methodology for determining the most economical use of maintenance resources. This is done so that the maintenance effort across a facility is optimized to minimize any risk of a failure(Carpitella et al., 2020).

A risk-based maintenance strategy is based on two main phases:

1. Risk assessment.

2. Maintenance planning based on the risk

The maintenance type and frequency are prioritized based on the risk of failure. Assets that have a greater risk and consequence of failure are maintained and monitored more frequently. Assets that carry a lower risk are subjected to less stringent maintenance programs. Implementing a risk-based maintenance process means that the total risk of failure is minimized across the facility in the most economical way.

The monitoring and maintenance programs for high-risk assets are typically condition-based maintenance programs. Risk-based maintenance is a suitable strategy for any maintenance plan. As a methodology, it provides a systematic approach to determine the most appropriate asset maintenance plans. Upon implementation of these maintenance plans, the risk of asset failure will below.

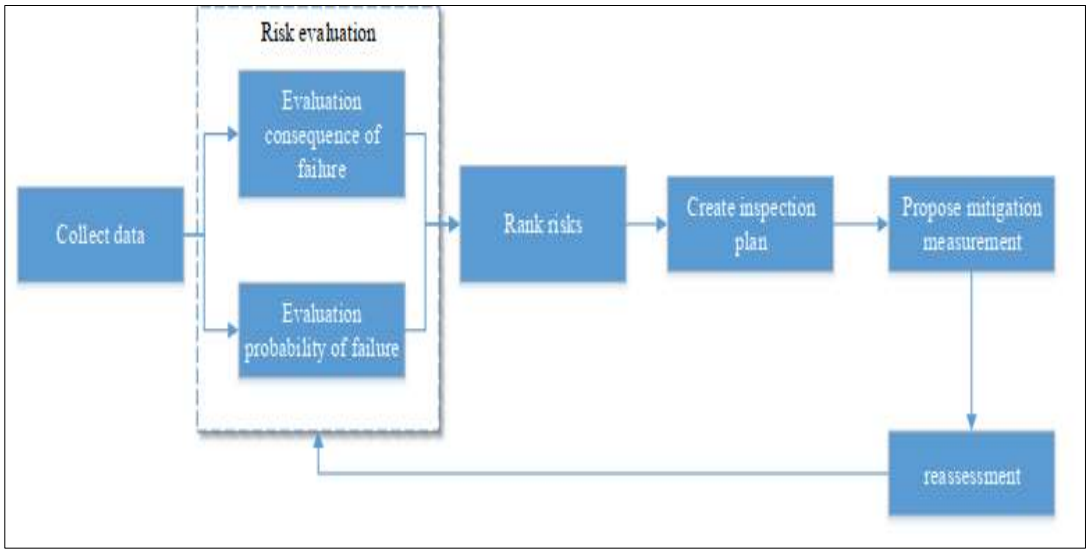

Figure 2.4. Risk based maintenance framework. Authors (Alaswad & Xiang, 2017)

Total productive maintenance

As Oakley and Ed 2021, discussion been held on direct process improvements using lean methods valuable in reducing waste that is a direct result of manufacturing practices. Total Productive Maintenance (TPM), however, focuses on continuous improvements based on reducing wastes related to machines and tooling used in manufacturing processes through a highly effective and efficient maintenance program.

Total Productive Maintenance (TPM) is an approach to maintenance developed in Japan that brings the tools of total quality management (TQM) to maintenance. The only change is that instead of companies focusing on their products, their focus shifts to their assets.

All of the tools and techniques used to implement, sustain, and improve the total quality effort can be utilized in TPM (Fonseca et al., 2017)The aim of TPM is to reduce six categories of equipment losses to improve overall equipment effectiveness (OEE).

The six major causes of equipment losses, according to (Kumar et al., 2018)are:

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

TPM empowers operators and uses multi-skilled crafts to minimize response time and perform productive maintenance. The implementation is expected to assist in improving maintenance effectiveness and control (Lundgren et al., 2018) according to (Bakri et al., 2020)TPM is an innovative approach, which holds the potential for enhancing the efficiency and effectiveness of production equipment by taking advantages of abilities and skills of all individuals in the organization, TPM focuses on maximizing the Overall Equipment Efficiency (OEE) with involvement of each and everyone in the organization. It will not only establish a complete maintenance system, but also aims to improve the maintenance skills and knowledge among the shop floor operators(Alaswad & Xiang, 2017), TPM and its implications received prestigious worldwide recognition in achieving the ultimate Zero Defects and Zero Breakdown targets. Fewer breakdowns, safer workplace and better overall performance are few advantages of TPM.

Under the TPM philosophy, everyone from top-level management to equipment operators should participate in maintenance.

- Top management & reliability engineers
- Maintenance managers and technicians
- Operators

Table 2.4: CSFs for managerial process in MM (Bakri et al., 2020)

CSFs	Elements	Authors
Policy on MM	Clear company policy on MM; recognition of MM as vital constituent in management.	Mahzan et al., 2018; Pakrudin et al., 2017; Hooi and Leong, 2017; Mehralian, et al, 2016; Bakri, 2015; Kumar and Kumar, 2014; Zargun and Al-Ashaab, 2014.
Financial and resources support	Allocation of sufficient resources; offering rewards and incentives.	Kumar and Kumar, 2014
Education and training	Knowledge and competencies; development on employee competency	Mahzan et al., 2018; Pakrudin et al., 2017;Mehralian, et al, 2016; Bakri, 2015;
Equipment and facility upgrading	Continual improvement of equipment and facility; Inculcate the Kaizen culture	Pakrudin et al., 2017; Bakri, 2015
Communication	Open communication and exchange of information; feedback system; motivation.	Mahzan et al., 2018; Pakrudin et al., 2017; Bakri, 2015;
Performance measurement	Scheduled monitoring and follow-up; measurement of performance based on OEE; assessment on employee competency; enforcement by management.	Pakrudin et al., 2017;Mehralian, et al, 2016; Singh et al., 2014.

TPM is built on a 5S foundation, with eight supporting pillars. The beginning of a TPM program will focus on establishing the 5S foundation and developing an autonomous maintenance plan. This will free up the maintenance staff to begin larger projects and perform more and more planned maintenance.

Figure 2.5. Foundation and pillars of TPM (Labiyi, 2019).

Starting the Kaizen activities through implementing the basic three pillars which include the five steps of housekeeping (5S‟s), standardization and muda elimination. According to (Labiyi, 2019), the five steps of housekeeping are:

Sorting: it is a process that involves selecting what you need to complete the job and removing everything else from your work area.

Set in Order: Straightening specifically customizes your workstation and surrounding area to meet your work area needs. Arrange remaining items so they are easy to select, use, and return to their proper location.

Shine: Its Emphasis is on the removal of dust, dirt, and grime. It focuses on cleaning up the place now that all the disorder and trash has been removed.

Standardize: Standardizing creates a work area free of checklists; if appropriate standards are put in place, it will be easier to maintain and continue improving, by implementing this we make sure that the first three steps are maintained.

Sustain: Sustaining is the end result of how well we have performed the previous four S's, the idea Sustain is implementing the 5S will demand from workers the compact self-discipline connected with implementing and obeying the rules of regularity in cleaning and sorting.

Value Driven Maintenance

(Lundgren et al., 2018), original cited by Senstrom et al., (2013), Value-driven maintenance (VDM) is not a maintenance type, but rather a philosophy developed by the founders of Mainnovation, Mark Haarman and Guy Delahay, for optimizing the value derived from maintenance at any particular point in time VDM is a maintenance management model with the aim of adding value and profit to the company.

The value drivers in maintenance are described as utilization, resource allocation, cost control, and safety, health, and environment (HSE). Net present value is used in VDM as a measurement of profit calculated by the difference in cash inflows and outflows from the different value drivers. It gives an indication of how much value an investment or project will add to a company, and is used to analyze the profitability of investment suggestions is calculated as below formula of authors(Lundgren and Bokrantz 2018) .

$$\text{PVPM}=\sum(FSHE,t)+[CFCC,t)+(CFRA,t)+(CFSHE,t)]/(1+r)*t \qquad (2.1)$$

Where: PVPM: present value potential of maintenance

FSHE,t: She factor in a year t (% compliance with SHE regulations

CFAU,t: future cash flow in year from asset utilization

CFCC,t: future cash flow in year t from the cost control

CFRA,t: future cash flow in year t from resource allocation

FSHE,t: future cash flow in year t from She

r: discount rate

Total Quality Maintenance (TQMain)

Mahajan 2018,studied the concept which enables the user to continuously maintain and improve the technical and economical effectiveness of manufacturing process elements and its role may be defined as "a means for monitoring and controlling deviations in a process condition and product quality, and for detecting failure causes and potential failures in order to interfere, when possible, to arrest or reduce deterioration rate before the product characteristics are intolerably affected and to perform the required actions to restore the machine process or a particular part of it to as good as new. All these should be performed at a continuously reducing cost per unit of good quality product".(Alsyouf, 2017).

Features, Applicability and Benefits of TQMain

The features characterizing TQMain and distinguishing it from other maintenance techniques, such as preventive (PM), condition-based (CBM), reliability-centered (RCM) and total productive maintenance (TPM) can be summarized in the following based on (Lundgren et al., 2018) (Alsyouf, 2017)(Al-Najjar, 2008). It is based on a new CBM concept. It is planned and performed based on the needs arise due to the deviations in the quality of the elements involved in the production process.

- It advocates the use of a common database that should be updated by real-time measurements of the essential information parameters, for real-time monitoring and assessment of the machine condition and production process technical and economic effectiveness, product quality and working environment. Thus, within TQMain, it is possible to select and improve the most informative CM system and the most cost-effective maintenance policy effectively.

- It is based on making intensive use of the real-time data acquisition and analysis to detect at an early stage the causes behind quality and cost factors deviations and machinery malfunctions, and following damage/defect development to prolong the component mean effective life and to improve company's profitability and competitiveness.
- It provides tools and methods for proactive-predictive maintenance, to detect and eliminate the cause behind damage initiation. If it is not possible due to the technological limitation, detect the deviation at an early stage and predict its development to reduce (or eliminate) the risk of failure.

2.5. Maintenance management

As a author Lu et al. 2020, A good maintenance management system makes equipment and facilities available, Availability means the production team can demand and receive any item such as light, power, air, gas, heating, cooling, or machine tools when it is needed. If the required equipment or service is down, or if the machine stops short of completing a job, time and money are wasted. A good maintenance management system helps to accomplish minimal downtime.

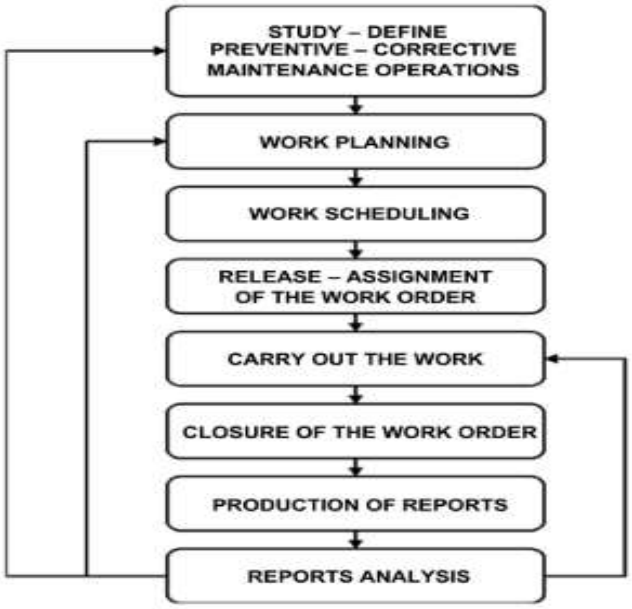

Figure 2.6. The maintenance workflow (Keat, and Ya'akob 2021)

Basic steps of management stated by Fusko et al., 2018 are request, approval, plan, schedule, performing work, recording data accounting for costs, developing management information, updating equipment history and providing management control reports. Elements of effective maintenance management includes

i. Maintenance Policy:
ii. Material Control
iii. Work Order System
iv. Equipment Records
v. Preventive and Corrective Maintenance
vi. Job Planning and Scheduling
vii. Backlog Control and Priority System
viii. Performance Measurement

2.5.1. Maintenance management framework

In this section former developed frameworks are reviewed. Maintenance must be considered holistically so as to develop an appropriate maintenance concept.

Maintenance Framework 1

Vanneste & Van Wassenhove, 1995a, present a brief review of developments in maintenance theory and practice, and in information technology and decision support models. The model is an integrated approach that combines elements from these domains into a powerful tool for dealing with maintenance problems. They also show how this framework can be used to set up a continuous improvement program for maintenance management and apply the concepts to an industrial case. This approach has eight stages by improving the Deming cycle.

Phase 1 Obtain a clear picture of the current factory performance: at this stage list of questions developed in order to have a clear picture of the organization.

Phase 2. Analyze quality and downtime problems: At this phase location of the majority quality and downtime problems, relative importance, frequency of occurrences, causes and consequences identified by using histogram, pareto analysis, quality control charts, cause and effect diagrams, FMEA methods. Phase 3. Analyze the effectiveness of alternative solutions for major problems. Different solutions generated and their hidden and tangible costs identified. They mentioned that both costs as well as benefits of a solution, especially in the hidden part are uncertain and difficult to estimate an exact value.

Therefore, it is necessary to include scenario analysis by comparing one solution cost benefit analysis with another solution, it became easy to prioritizes the proposed solutions.

This phase has 4 steps are:

1. Obtain a list of alternative solutions to each problem.
2. Estimate the cost and benefits of major solution.
3. Make a prioritized list.
4. Select one or more solution

Phase 4. Analyze the efficiency of maintenance procedures, to identify how much preventive maintenance be to performed, how many spare parts to be kept in stock decision models used. The input for the models such as cost, lifetime distribution is obtained from effectiveness analysis, additional data analysis and experts opinion. At this phase 3 models selected, maintenance and replacement model (it is a maintenance field), spare part provisioning model (it is under Inventory management) and scheduling model (it is under production scheduling). Three models under maintenance and replacement model selected, these are Deterministic age replacement model, Probabilistic age replacement model and group replacement model. a common factor among these models is that the unit deteriorates as it ages.

Phase 5. Plan action. Planning of actions and information process takes place to keep the track of the result. After defining performance measures and organizing the data gathering process target will be set.

Phase 6. Implement actions and gather data. Planned actions on phase five will be implemented and data's' will be collected.

Phase 7. Monitor actions and process data. And the last phase will be adapting actions or information procedures in case of undesired evaluation. Performance Indicators (P.I.'s) provide a tool to measure certain quantities and check whether and to what extent objectives are being met. In the integrated approach, the effectiveness analysis precedes the effectiveness analysis.

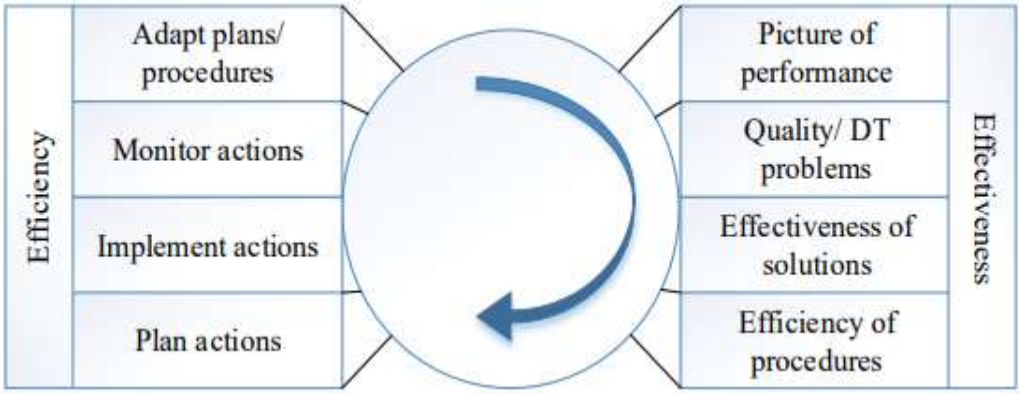

Figure 2.7: framework 1 (Vanneste & Van Wassenhove, 1995a)

Framework 2

This framework offers guidance for developing a tailored maintenance concept, The paper emphasized that Maintenance concept should be unique for each company due to two reasons. One is the relevant factors are different from company to company and the other reason is high speed technological innovations. Due to this a flexible maintenance concept that allows feedback and improvement needs to developed. nowadays great emphasis is put on the availability, reliability and safety of production. Computerized information used for information source in addition to that workers' experience and know-how (knowledge) considered.

The framework was developed for a large process industry with the goal of developing total company maintenance for all different plants and all different installations. The proposed framework has six steps.

Step 1. Identification of objectives and resources: the first objective of maintenance is to secure reliability and availability, to reduce cost, protect their commercial margins, to meet the severe laws of safety and environment and to enhance productivity.

Step 2. Identification of most important system: Depending on the objectives and the situation, weight factors can be used to underline the relative importance of each objective concerning bottlenecks, loss of production. Step 3. Criticality analysis: here the most critical component with in the selected most important system identified. A simplified FMECA used in table form, economic and technical aspects and knowledge in human's head considered. The reason for

this approach is that technical systems deal with layout, flow and equipment for that their performances visualized in terms of breakdowns, set-up losses, minor stoppages and quality defects.

Step 4. Maintenance policy decision steps: decision tree with the consideration of technical and economical aspect followed.

Step 5. Optimization of preventive maintenance policy: after the maintenance policy selected its parameters such as PM frequency should be optimized. In maintenance there are basic strategies block based and age based, Block based (time-based) strategy is an extension of block based. Both policies are based on renewal theory and the difference between the basic model and the extended one lies in the duration of the maintenance interventions (zero and finite respectively)

Step 6. Performance measurement and continuous improvement: two reasons stated for limited maintenance performance measurement. The first is maintenance performance reporting is difficult and the other reason is maintenance is closely related to other activities. Most of maintenance performance indicators are ratios measuring effectiveness, efficiency and productivity. As shown in figure 2.8, generally the proposed framework has five modules.

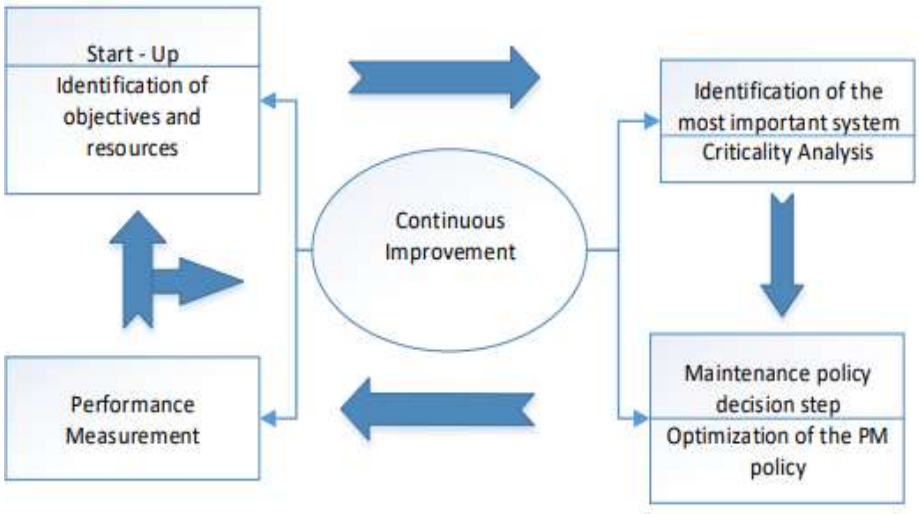

Figure 2.8. schematic overview of the proposed framework (Waeyenbergh and Pintelon, 2002)

Maintenance Framework 3

Marquez divides maintenance management process as the definition of maintenance strategy from business strategy in order to reduce maintenance indirect cost and the implementation of maintenance. These functions are effectiveness; efficiency; assessment; and improvement, under effectiveness first maintenance objectives and associated KPIs defined.

The Last phase is continuous improvement and maintenance management through maintenance accurate and precise data flow clearly shown. Total productive maintenance is another way for continuous improvement and maintenance management that is suggested on the maintenance management framework.

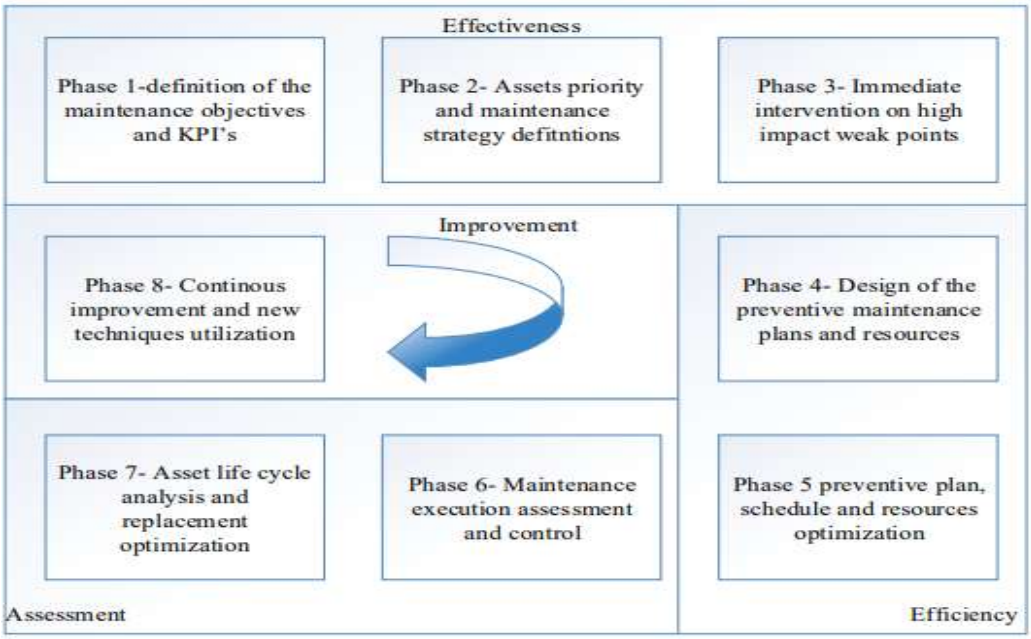

Figure 2.9. Maintenance management framework (Marquez et al., 2009)

Maintenance framework 4

The developed framework known as CIBOCOF which means Centrum voor Industrieel Beleid Onderhouds Concept Ontwikkelings Framework, or in English, Centre for Industrial Management Maintenance Concept Development Framework. It helps to developed customized maintenance system for a specific company. the framework is deals with a PDCA approach and contain five modules.

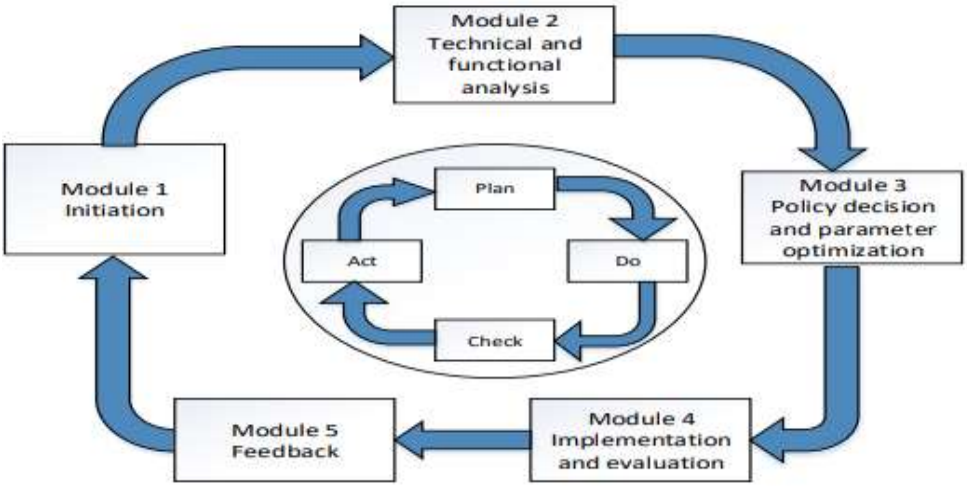

Figure 2.10. CIBOCOF framework (Waeyenbergh, 2020)

Framework 5

This framework is developed by Naughton and Tiernan (2012), obstacles to develop individualized maintenance concept are stated. Among those lack of respect for practitioners, lack of respect for experience, lack of management support, lack of process knowledge, fear of change mentioned. nine-step of maintenance framework for developing and implementing an individualized maintenance strategy are revised under this stage.

Step 1. Focus on the positives and define one's position: first a company has to make a critical review about its pre-existing maintenance functions by asking important questions and identifying all resources/deficits, to do this team will be created that have a member from all stakeholders, appreciative inquiry method used and the generative objectives of maintenance clearly stated at this step.

Step 2. Identify constraints and limitation: FMEA table used to rank complexities that affect maintenance, in light of the new identified constraints objectives revised.

Step3: system classification: as per the criticality analysis machines are classified in to different categories, each category critical component identified by using FMEA.

Step 4. Machine classification: once system classified at step 3 further classification of machine and components done here by using sliding scale.

Step 5. Policy selection: tacit and explicit knowledge of preexisting maintenance staffs are used to select maintenance policy. More than one policy can be used at a time within the confines of the framework.

Step 6. Aligning performance indicators: plant wide indicators reflect the performance of the maintenance function on three different levels; availability of resources, value or return on investment and technical.

Step 7. Structure maintenance data: as data builds up, the benefits of having an individualized maintenance framework becomes apparent, the quality of recorded data is critical importance for the interaction with computerized maintenance management system.

Step 8. Implementation and monitoring: here maintenance framework for entire organization formulated and documented. In order to check formulated framework, it is tested on sample line and monitored intensively.

Step 9. Feedback: because of its dynamic nature small period adjustment made by conducting continuous review of the individualized framework. Like any continues improvement process each iteration bring more and more gains. Limitation of this model is that the model is more dependent on tactic knowledge which is very different from person to person. It might be a false information.

Framework 6

It is a proposed maintenance framework by Wireman in the form of a pyramid structure. It consists of 11 blocks consisting of 5 levels.

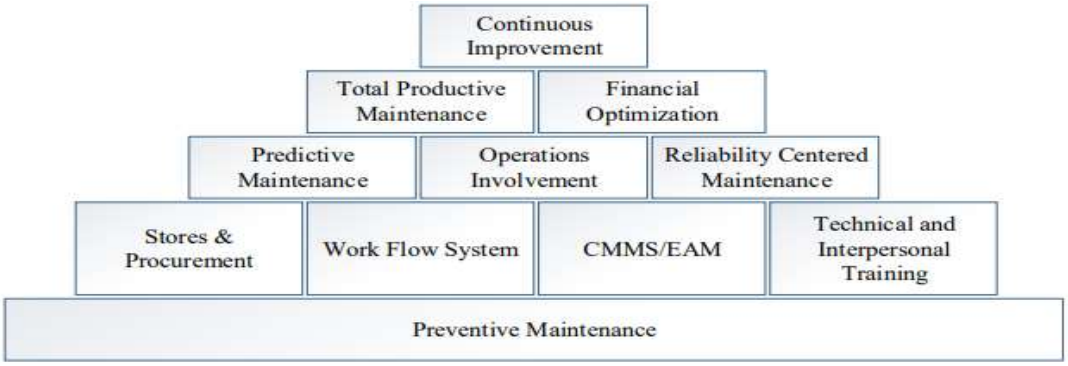

Figure 2.11. Maintenance management framework (Wireman, 2005).

Framework 7

Campbell (1998) original sited by Hesham (2015) developed maintenance management framework in to four levels. The first level is development of maintenance strategies for the assets and associated human resource implications of any changes to the working culture. The second level focuses on monitoring and control of individual assets during their lifetime to make sure that they perform to their designed functions in full, development of a measurement system so that performance metrics can be gathered, planning and scheduling of maintenance activities and eight maintenance tactics. The third level covers the application of TPM and RCM for continuous improvement. The fourth level is about maintenance re-engineering. (Hesham, 2015).

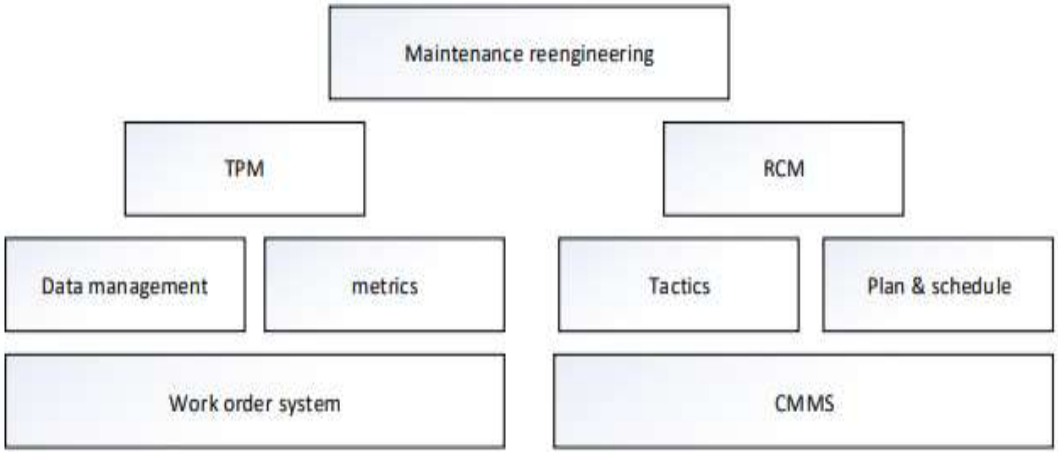

Figure 2.12. maintenance management framework (Hesham, 2015)

Framework 8

Three block maintenance management frameworks proposed by Somesh Kumar Sharma (2013) to redesign the methodology of plant maintenance for effective and continuous maintenance development. Lack of appropriate combination of methodology and maintenance approaches; the missing link between maintenance management components such as objectives and strategies, human aspects, support mechanism, tools and techniques, organization as well as between high performance and competitive advantage are the two main identified gaps in the literature that are addressed in the newly developed maintenance reengineering framework.

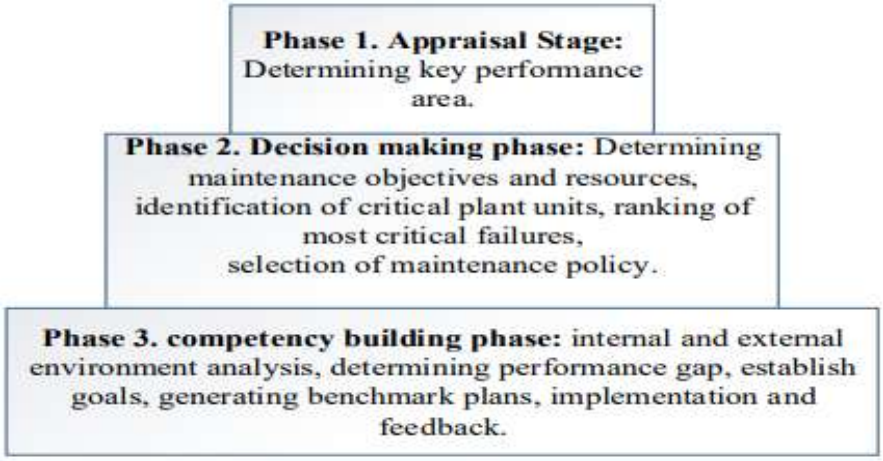

Figure 2.13. maintenance reengineering framework (Sharma, 2013)

According to Faccio et al 2014, framework is quantitative that helps to develop optimal maintenance policies, using several cost models, based on simple but relevant costs, like spare parts, labor, missing production costs and other indirect costs. Its focus is limited to failure-based maintenance and use-based maintenance policies since these are the most common methods applied in industrial systems. The authors extend their approach also to the statement of predictive maintenance policies for many policies, included CBM. The framework is developed based on a framework developed by Waeyenbergh, 2002 with improvements particularly on final steps regarding the economic evaluation of different maintenance policies. a general quantitative framework to solve planning problems in maintenance policies; its focus is limited to FBM and UBM (in particular Age replacement policy) policies since these are the most common methods applied in industrial systems.

Based on the Research report of Keat and Ya'akob 2021 maintenance management framework defined aging and aging equipment as "aging is not about how old an equipment is, it is about its condition, and how that is changing over time. All types of equipment can be susceptible to aging mechanisms. Alaswad and Xiang 2017,The significance of deterioration and damage related to potential effect on equipment's functionality, availability, reliability, and safety." The issue of aging plant leading to an increased risk of containment and other failures due to plant and equipment deterioration demonstrates the significant extent and impact of aging plant-related failures on safety, environmental, and business performance (Monrose & Tota-Maharaj, 2018).

According to Keat et al., 2021, The seven subject groups and related subject elements are shown in Figure 2,.7, with each element further described and defined in subsequent sections of the document. The subject groups are: 1. Business Requirements 2. Maintenance Strategy Management 3. Maintenance management 4. Maintenance execution 5. Deliverables
6. Continual improvement 7 Allocation of resources.

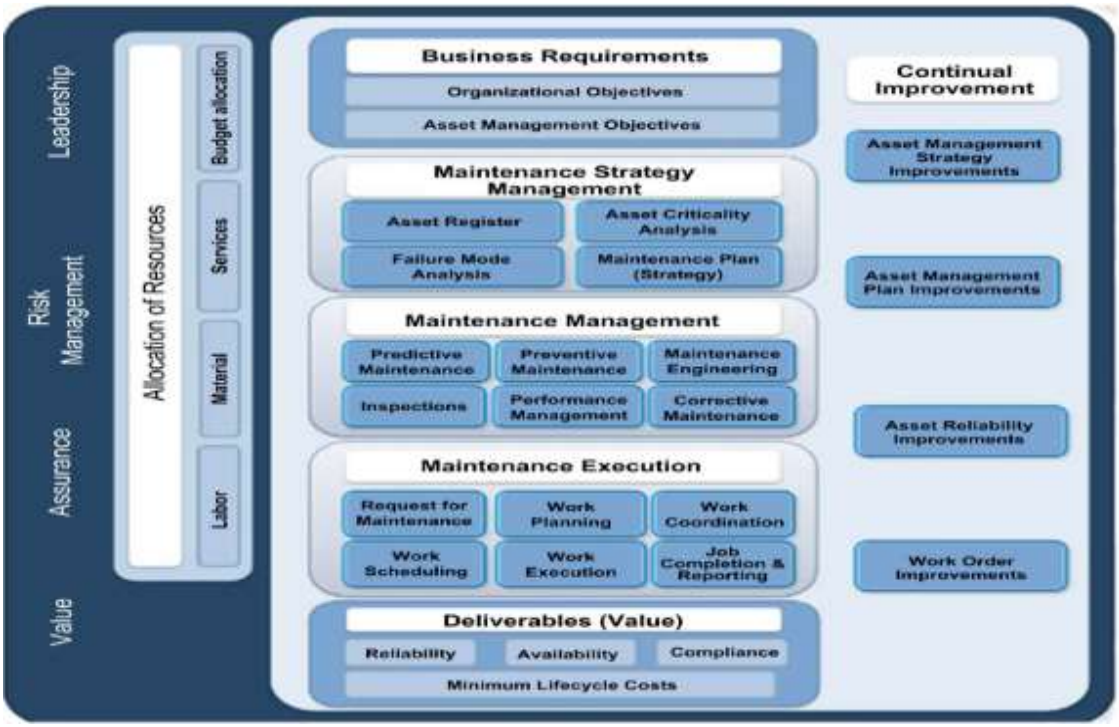

Figure 2.14. The maintenance management framework (Keat and Ya'akob 2021)

Maintenance Management Tools and Techniques

On previous developed frame works different tools and techniques such as balanced scorecard, criticality analysis, OEE, failure root cause analysis, reliability centered maintenance, reliability analysis, critical path method, life cycle cost analysis, critical success factor, current reality tree, fault tree analysis, 5S, reliability blocked diagram, cause and effect diagram etc. used(Dzulkifli et al., 2021).

FMEA (Failure Mode and Effect Analysis)

FMEA is a planning tool designed to recognize and keep the potential problems from occurring. The procedure of this method starts with identifying the mode of possible and also unknown failure and correlate those failure modes with potential causes and effects. In the next stage, the failure is ranked based on three parameters which are the occurrence, detectability and severity.

The result of multiplication of these three parameters form Risk Priority Number (RPN) that can be expressed as in (Ismail and Kamal 2020).

$$RPN = S \times O \times D \quad (2.2)$$

Where, S is for failures severity, O is for probability of failure occurrence and D is for detectability of failure before occurring.

FTA (Fault Tree Analysis)

Mohamed and Khodeir 2019, Fault Tree Analysis (FTA) is a system safety tool for modelling chains of cause and effect leading to some undesirable event, such as an accident. All procedural and equipment-related causes are considered, so it is more flexible than FMEA and has been used for safety analysis and equipment/procedure design in many industries, including defense, space, and nuclear power generation. The chain of cause and effect is modelled as a Boolean Tree, with alternating levels of and-gates and or-gates describing the logic of the focal (head) event(Marugán and Pinar Pérez 2016).

RCA (Root Cause Analysis)

A root cause is a factor that caused a non-conformance and should be permanently eliminated through process improvement. RCA is a collective term that describes a wide range of approaches, tools and techniques used to uncover causes of problems (Monrose and Tota-Maharaj 2018).

OEE

Instead of (Franciosi et al., 2018b) proposed the new OEEE (Overall Environmental Equipment Effectiveness) indicator to evaluate the environmental impact of asset life cycle. Also (Er-ratby & Mabrouki, 2018) OEE is a method to understand the performance of the manufacturing area, but also to identify possible limitations.

Pareto Analysis

The Pareto analysis is the key process identifier in the root cause prioritization activity(Oakley et al., 2021) it is a bar graph made of a series of bars whose heights reflect the frequency of problems or causes. The bars are arranged in descending order of height from left to right.

Cause and Effect Analysis

The effect or the impact on the customer resulting from the failure mode; and the cause(s) or means by which an element of the design resulted in a failure mode. It is important to note that the relationship between and within failure modes, effects and causes can be complex. For example, a single cause may have multiple effects or a combination of causes could result in a single effect. To add further complexity, causes can result from other causes, and effects can propagate other effects(Zhang & Zhang, 2021).

Maintenance software

A computerized maintenance management system (CMMS) is a computer software program designed to assist in the planning, management, and administrative functions required for effective maintenance. Proper utilization of CMMS in the plant improves the reliability of equipment's, which is essential for its optimization(Pann and Tewari 2019). According to Dzulkifli et al., 2021 technology is inevitable in our daily lives in the globalization era and primarily functions to make things easier and solve problems. Maintenance software that can easily record and track data is an excellent alternative to maintenance management that constantly deals with complaints.

Benefits of a CMMS

Oakley and Ed 2021,Justifying a CMMS financially is not as easy to define. Proving the value of a CMMS to a company is difficult to put in numbers, due primarily to the following concept: maintenance is not about generating profits; maintenance is about avoiding costs. Carpitella et al. 2020, qualitative reasons are relied upon to justify the expenditures for a new or upgraded CMMS Perhaps a catastrophic event that resulted in a production loss or breach of health and environmental issues, attributed to "misinformation", could persuade company management to approve the expenditure. In any case, proposals for capital are usually approved if they can show increased profits and/or cost savings. Some of the common expected benefits include:

- Increase Availability of equipment.
- Reduce costs
- Reduce downtime
- Reduce spare parts inventory
- Reduce emergency work

2.6. Maintenance and Performance

The performance measurement of maintenance work is an important aspect in maintenance management. The objective is to measure whether the maintenance activities are adequately

efficient. One of the performance indexes for measuring the efficiency of a maintenance work can be availability (A) of the machine(Rukijkanpanich & Pasuk, 2018).the following criteria can be used for measuring the effectiveness of maintenance function(Er-ratby & Mabrouki, 2018).

$$Maintenance\ cost\ index = \frac{Maintenance\ Cost\ Down\ time\ hours}{Capital\ cost} x100$$

$$Productivity\ of\ maintenance = \frac{Output(product)}{Maintenance\ cost(product)}$$

$$Down\ time\ index = \frac{Down\ time\ hours}{Production\ hours} x100 \qquad (2.3)$$

2.7. Maintenance performance measurement

Er-ratby and Mabrouki 2018, Maintenance Performance Measurement (MPM) is defined as the multidisciplinary process of measuring and justifying the value created by maintenance investment and taking care of the organizations stockholders requirements viewed strategically from the overall business perspective and the importance of MPM as follows:

- Allows companies to understand the value created by maintenance
- Re-evaluate and revise maintenance policies and techniques
- Justify investment in new trends and techniques

2.7.1. Performance indicators, drivers and killers

Maintenance management functions to transform inputs include people, capital, energy, materials and technology into outputs namely goods and services(Nuratirah & Salmiah, 2018). Three types of performance indicators found on Er-ratby & Mabrouki, 2018 literatures, leading indicators that measures inputs as a process it measures future events, Coincident indicators that shows the performance while occurring and lagging indicators that measures output as a process it measures events that have already occurred . The leading indicators are even more important than lagging indicators because they have the potential to avoid unfavorable situations from occurring. performance killers are process inputs that leads to poor performance.

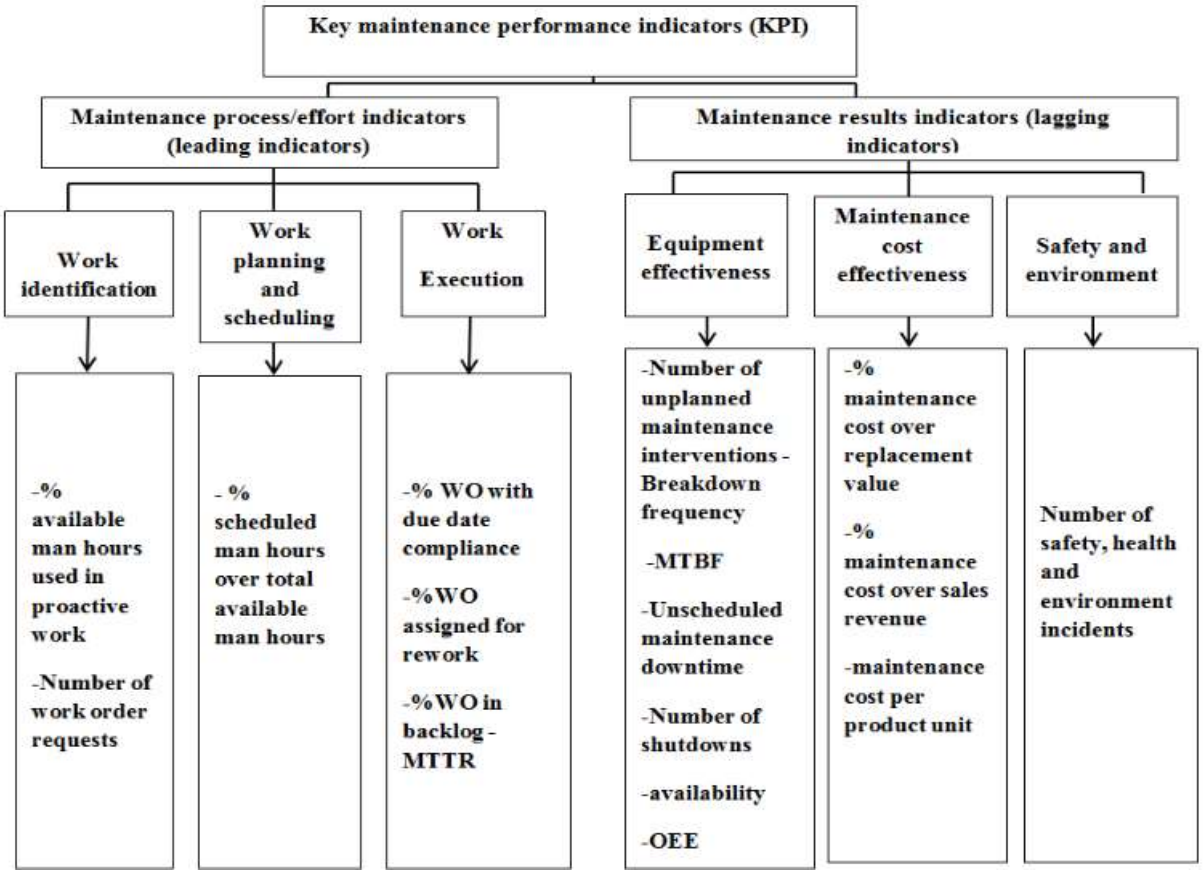

Figure 2.15. Key Maintenance Performance Indicators. Authors (Er-ratby and Mabrouki, 2018)

2.8. Maintenance in Transport industry

Effective transport management is an important activity in every successful organization in the logistics industry and for that matter fleet management businesses that have the intention of excelling in their fleet management operations in today's competitive market have to adopt effective and robust managerial strategies to coordinate resources that will facilitate their success and enable them to gain competitive advantage(Cimino and Fumagalli 2019). Vehicle repair and maintenance is very important to any fleet management organization. Repair and maintenance captured issues of changing oil, routine servicing as well as managing spare parts. driver training, vehicle maintenance and vehicle design are range of relative low cost measures that can save 10% or more fuel for fleet operation (Kraa and Agbenyo, 2020)

2.8.1. Maintenance Challenge in Transport industry

The transportation industry is under tremendous pressure, companies have to move goods from point A to point B in the face of unpredictable conditions however, some of these challenges can be remedied with automation upgrades capable of improving both speed and efficiency while contending with staffing challenges and the increasing demand for goods(Hwang Samat, and 2019).

2.9. Research gaps

Çınar et al. 2020, maintenance concept was considered all relevant factors of the situation on hand, which was tailored to the needs of the company in question, this means that the 'optimum' maintenance concept. Since industrial systems evolve rapidly, the maintenance concept was reviewed periodically in order to consider the changing systems and the changing environment. A lot of maintenance concepts were described in literature, offering interesting and useful ideas, most of them are highly resource intensive in terms of manpower and management attention. Applying standard concept readily available from literature is not always the best thing to do. Moreover, this makes the development and implementation of a maintenance concept difficult in practice. However, researchers on this area Velmurugan, 2015 was agreed by developing a customized maintenance concept the above shortcomings will be addressed that the new maintenance concept must fit the objectives and the culture of the company, as well as the existing maintenance organization.

1. Available maintenance management systems are very few in number since many of the concepts are only valid for a special class of equipment or a specific industry.
2. Till now framework or maintenance management system found not for Transport industry.
3. Literature review revealed among other frameworks, maintenance framework developed by Alhouli et al., 2017 is relatively better than other frameworks. However, it has limitation on work flow system and data management.

In Ethiopian Shipping & Logistics Services Enterprise Kality in Land Transport Branch practice of good maintenance strategy was a problem since a lot of break downs, quality of spare parts, lack of training and maintenance recording data. This research was focused to minimized these problems.

CHAPTER -3

3. Materials and Methods

3.1. Research Method

This study has been used two kinds of sources to collect information, primary and secondary sources. Primary sources focused on information which helps to have the entire understanding of the study through different techniques such as interviews, questionnaires, & discussions. Whereas secondary sources of information related with the study to have detail understanding with the supportive documents and reports. To make effective the collection has been used two methods, quantitative and qualitative method. Quantitative implies that the way of collections which can be described, counted, and measured in certain amount. Thus, the result can be expressed in number and can be formulated. But qualitative method has been a different way of expression in reverse that can't be expressed in figure.

3.1. 1. Data collection method and tools

The methodology followed to approach with reliable results, collecting data on the current maintenance system, maintenance organization, production constraints. The downtime, critical Trucks breakage, lack of technician's training was believed to indicate the appropriate maintenance functions various survey methods used to assess the current situation of the company. Primary Data Primary data defined as data collected by a program of observation qualitative and quantitative method either separately or in combination to meet the specific objective of the research.

a. Physical observation/case study

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

b. Survey questionnaires

The survey questionnaires for assessing the maintenance system in the company are designed. To gather data about the organization and maintenance management practices adopted by ESLSE., an open ended and closed types of collective questionnaire developed. as far as data collection tools were concerned, the conduction of the research involved the use of depth

structured questionnaire, which was used as an interview guide for the researcher. Some certain questions were prepared, so as for the researcher to guide the interview towards the satisfaction of research objectives, but additional questions were made encountered during the interviews.

Interview: semi structured interview followed to collect necessary information from employees on managerial level. Maintenance and engineering department manager has been interviewed. The main advantage of personal interviews is that they involve personal and direct contact between interviewers and interviewees, as well as eliminate non-response rates, but interviewers need to have developed the necessary skills to successfully carry an interview.

Secondary Data

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

c. Literature survey

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

d. Document retrieval

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

3.2. Sampling and sample size

Among the types of sampling techniques, random, non-random and mixed sampling techniques for this study non-random sampling is selected which is purposive sampling is selected. This type of sampling is extremely useful to construct a historical reality, describe a phenomenon or develop something about which only a little is known. this sampling strategy is more common in qualitative research. It is also possible to use this technique in quantitative researches (Huang, 2020). the purpose of sampling in quantitative research is to draw inferences about the group from which the sample will be selected, whereas in qualitative research it is designed either to gain in depth knowledge about a situation/event/episode or to know as much as possible about different aspects of an individual on the assumption that the individual is typical

of the group and hence will provide insight into the group. due to the above reasons, it is suitable for this study.

Sample size: there are a total of 170 employees under maintenance department. therefore, maintenance and engineering staffs was participating for data collection. In addition, Truck driver and Analysis staffs was participating to understand impact of maintenance on quality. Therefore, total number of participants with their position will be as follow.

Table 3.1: Participants for data collection with their respective position

S. No.	Department	Position	Quantity
1	Admin.	Plant Manager	01
2.	Maintenance and Engineering	Maintenance and engineering department manager/Deputy plant manager	01
3		Supervisors (Maintenance supervisor, utility supervisor and workshop supervisor)	10
		Mechanics (General mechanic, Auto mechanic, senior mechanic& Senior Auto mechanic)	30
		Electrician (Junior electrician, senior electrician)	05
		Experts(inspectors)	05
		Workshop staffs (machinist and winder)	05
4	Truck Drivers	Ethio-Djibouti & other internal country	03
5	Analysis	Under maintenance dep & Planning dep.	07
	Total number of employees		67

3.3. Data Analysis

Collected data sorted, organized and coded for analysis statistical data tools such as tables, graphs and charts used. On previous maintenance management frameworks different tools and techniques used to develop the framework. Among those tools Failure mode and effect analysis, histograms, quality control charts, Overall Equipment Efficiency, failure root cause analysis, reliability centered maintenance, reliability analysis, critical path method, critical success factor, current reality tree, fault tree analysis can be mentioned (Marquez et al., 2009, Alzaben, 2015). Therefore, in data analysis part, following the method that used in data collection analysis has been shown clear image of the existing system for the ease of finding an

appropriate solution. Both data from existing company and from questionnaire were analyzed by means of computer software i.e., Microsoft Excel 2021, Pareto and Statistical Package for Social Sciences (SPSS). Finally, the data were compared with the written approach in literature survey for finding new and possible maintenance system approaches.

3.4. Research framework

The research starts by doing preliminary research assessment and gap identification. The next step is formulation of problems and objectives to do this literature survey performed and also experts in this area consulted. Therefore, at this stage research questions, objectives, problem statements developed and modeled and also expected results forecasted. After formulation of problems and objectives intensive literature reviews done so as to have a detail knowledge on maintenance, maintenance practice in Transport industry and any knowledge related to the subject matter. Next research design and methodology established by listing required steps of the process, preparing appropriate data collection tools. As per selected data collection method and analysis tools data collected, presented and analyzed. Then results discussed by interlinking with previous studies. Here improvement areas clearly identified and new maintenance management model developed. The framework address identified weakness throughout ESLSE Kality branch maintenance system, at this stage implementation procedure prepared, at last stage there will be conclusion and recommendation as per the result of the paper.

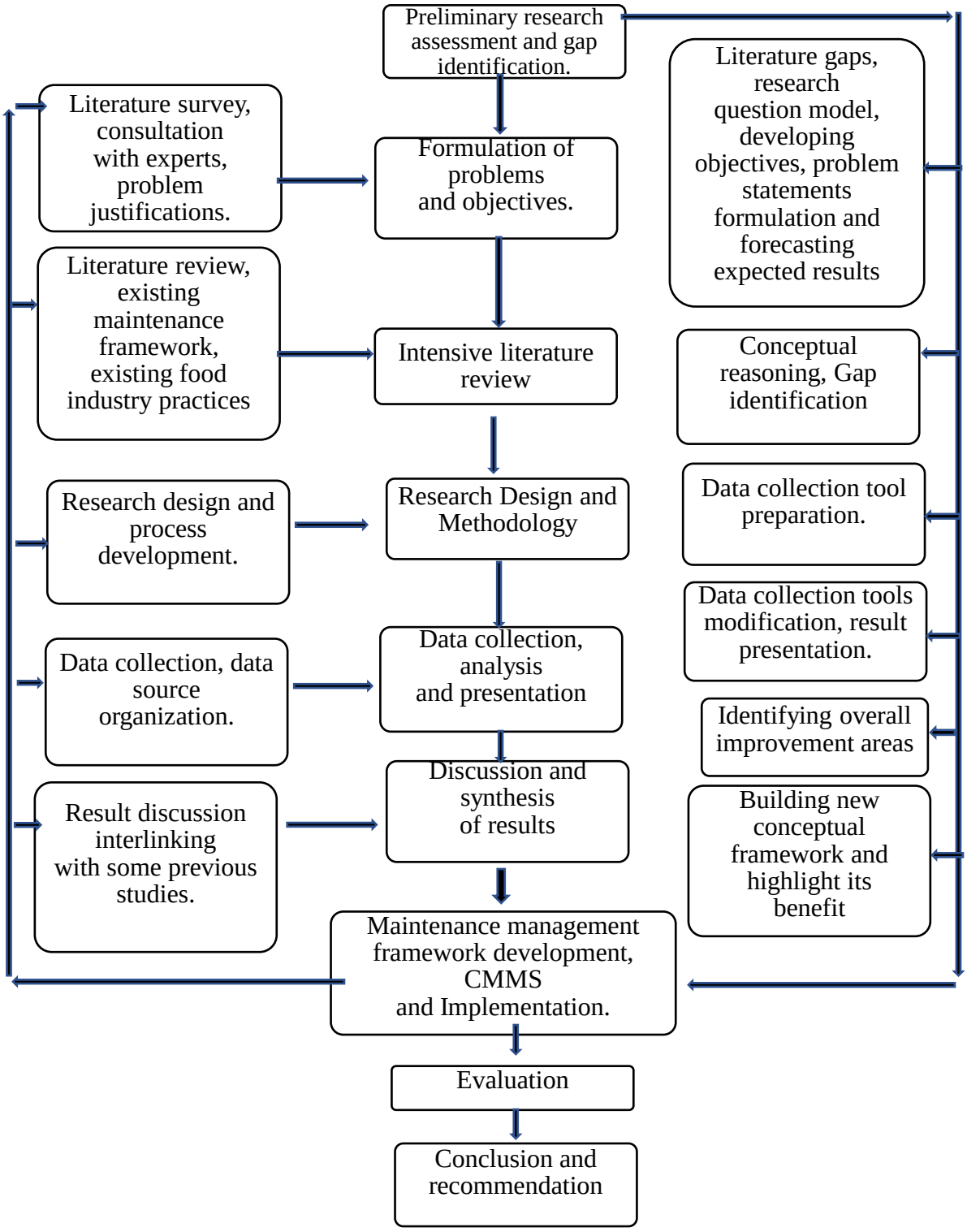

Figure 3.1: Research framework

3.5, Ethical Consideration

The study considered some ethical issues. This are the respondent experts and others have the right to respond or not, the respondent experts and others has the right to participate or not, the study has done to inform respondents the purpose of the questioner and the study considers the confidentiality of the response by not asking to state name. While conducting the study, emerging ethical issues has been considered and given attention.

CHAPTER - 4

4. Data Analysis and Discussions

For the purpose of gap analysis, a questionnaire was prepared, in order to evaluate importance and agreement of different maintenance practices in the Ethiopian Shipping & Logistics Services Enterprise Kality in Land Transport Branch company. to measure maintenance practices, respondents were asked to report the level of importance and agreement considering different maintenance activities.

The questionnaire was presented in the appendixes, in this chapter, the data has been collected from Ethiopian Shipping & Logistics Services Enterprise Kality in Land Transport Branch and presented the main analysis of this study with respect to the problem formulation. Hence, the presented theories are used in relation with the empirical finding to analyze the current situation at the company. General information: maintenance planner, maintenance supervisor, Team leader, Truck Driver, General mechanic and senior mechanic participated at 40.3 % of respondents has maximum of 16-20 years' work experience and also, they have educational background diploma and bachelor degree.

Table 4.1: General information

Position	maintenance planner, maintenance supervisor, Team leader, mechanic and senior mechanic			
Total year of experience	0 - 5 yrs.	6 - 10 yrs.	11 - 15 yrs.	16- 20 yrs.
Number of employees (in %)	13.4%	20.9%	25.4%	40.3%
Educational background Diploma 88.1% BSC 11.9%	13.4	20.9	25.4	40.3
Gender				
Male 90%	30	35	20	15
Female 10%	10	40	32	18

The current situation maintenance management system of Ethiopian Shipping & Logistics Services Enterprise Kality in Land Transport Branch is analyzed based on the summarized questionaries. from the survey questionnaire result the contribution of the variables to the maintenance problems as follows.

Table 4.2: Frequency Table for questions.

Maintenance technicians follow safety policies and procedures when they do their tasks.		
	Frequency	Percent
strongly disagree.	3	4.5
disagree	27	40.3
undecided	29	43.3
agree	7	10.4
strongly agree	1	1.5
Total	67	100.0
The equipment's are maintained within a short time when the equipment's failed.		
	Frequency	Percent
strongly dis agree	15	22.4
disagree	16	23.9
undecided	23	34.3
agree	12	17.9
strongly agree	1	1.5
Total	67	100.0
You have appropriate spare parts for maintenance.		
	Frequency	Percent
strongly disagree	41	61.2
disagree	21	31.3
undecided	3	4.5
agree	2	3.0
Total	67	100.0
Training concerning new technologies are provided frequently to the maintenance craft employees at your Company.		
	Frequency	Percent
disagree	16	23.9
undecided	32	47.8
agree	3	4.5
strongly agree	5	7.5
Total	67	100.0
Scheduled training programs are given on maintenance.		
	Frequency	Percent
strongly disagree	14	20.9

disagree	11	16.4
undecided	25	37.3
agree	12	17.9
strongly agree	5	7.5
Total	67	100.0
The organization has track record to evaluate how much it costs (Life Cycle Cost) to maintain equipment.		
	Frequency	Percent
strongly disagree	4	6.0
disagree	33	49.3
undecided	24	35.8
agree	6	9.0
Total	67	100.0
There is un availability of critical spare parts in the store.		
	Frequency	Percent
disagree	40	59.7
undecided	15	22.4
agree	4	6.0
strongly agree	8	11.9
Total	67	100.0
There is a permanent supplier of spare parts.		
	Frequency	Percent
disagree	24	35.8
undecided	13	19.4
agree	15	22.4
strongly agree	15	22.4
Total	67	100.0

For the questions given in maintenance organization majority of the respondents give a positive response that the company has a good overall structure of the maintenance organization but they have negative response about the management support consider maintenance activities.

In the training programs within maintenance most of the respondents answer that trainings concerning new technologies are not provided frequently to the maintenance craft employees at the company and there are no scheduled training programs which are given on maintenance. For the questions given in maintenance planning and scheduling the response of most of the respondents agree on the responsibility for planning the preventive work orders relies on

maintenance planner, they set priorities for maintenance job tasks and the equipment are not maintained within a short time when the equipment failed.

In the maintenance inventory and purchasing questions most of the respondents agreed on the control in the maintenance inventory of spare parts manually, but they didn't agree on prioritized critical components & strongly disagree that they have permanent supplier of spare parts. There are no standard work flow system previous studies revealed that work flow system is the information system for the maintenance organization and without the dedication to record all of the maintenance activities on a work order, the organization does not have the data to perform any meaningful analysis on its policies and practices, or more importantly on the equipment it is responsible for maintaining (Bakri et al., 2020). There is documented maintenance procedures and plans, it is not communicated down to the team due to these reason, technical staffs are not aware.

Generally, there is an indication that somehow the case company takes maintenance activities as an important function but there are limitations on

- Focus on proactive maintenance strategies.
- Record keeping and documentation on maintenance activities and history.
- Traditional workflow.
- Knowledge and skill gap on how to maintain a Truck, how to use maintenance tools and techniques
- Over all, unavailability of holistic and standardized maintenance strategy frame work across the board follows.

The reason behind the observed gaps is top management took maintenance as a necessary evil. This ideology controlled developed countries manufacturing companies on in 20th century but in recent years, industry managers have been gradually moving to the idea that maintenance can be a profit generating function rather than merely a cost center (Palakodeti, 2019).

Table 4.3: Frequency Table for questions for cause of breakdown.

What Causes Truck breakdown		
	Frequency	Percent
Lack of proper maintenance	11	16.4
Quality of spare part	14	20.9
Shortage of required spare parts	10	14.9
Unavailability of required tools and equipment's	5	7.5
Lack of skilled manpower	12	17.9
Lack of training of technical team	10	14.9
Lack of employee commitment	2	3.0
all	3	4.5
Total	67	100.0

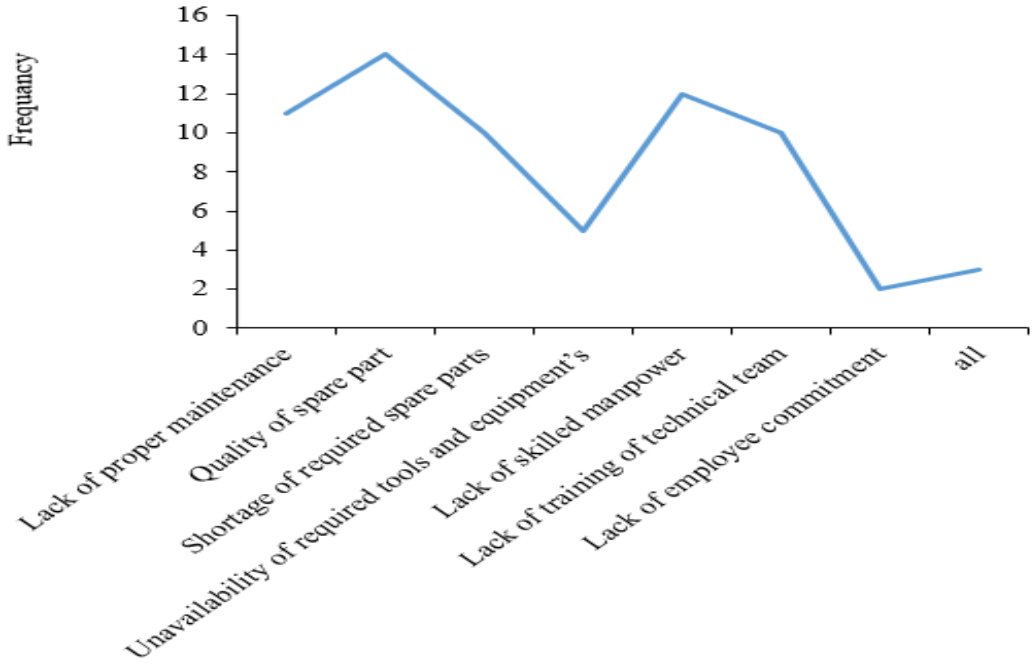

Figure 4.1: Causes Truck breakdown

From these results, the company faced with maintenance problems and reduced production efficiency due to lack of training programs, lack of quality spare part, lack of management

support about maintenance activities and frequent Truck downtimes figure 4.2 collected form driver where propeller shaft and Universal joint damaged by the Couse of quality.

Figure 4.2: lack of Quality

4.1. Documentation Review

The data below were explained and support to know the existing condition of the company using documented records from previous years. Quantitative data covered the period from 2011, 2012 & 2013e.c from four departments that's are planning, operation, Finance & maintenance department about Truck down time status on previous years as per recorded data. Thus, selected necessary data are presented in the appendix part:

According to figure 4.3 breakdown on September was higher than the other by the Couse of under the light repair maintenance value get the higher from the other causes that shown on figure 4.4 and it the data attached on the appendix.

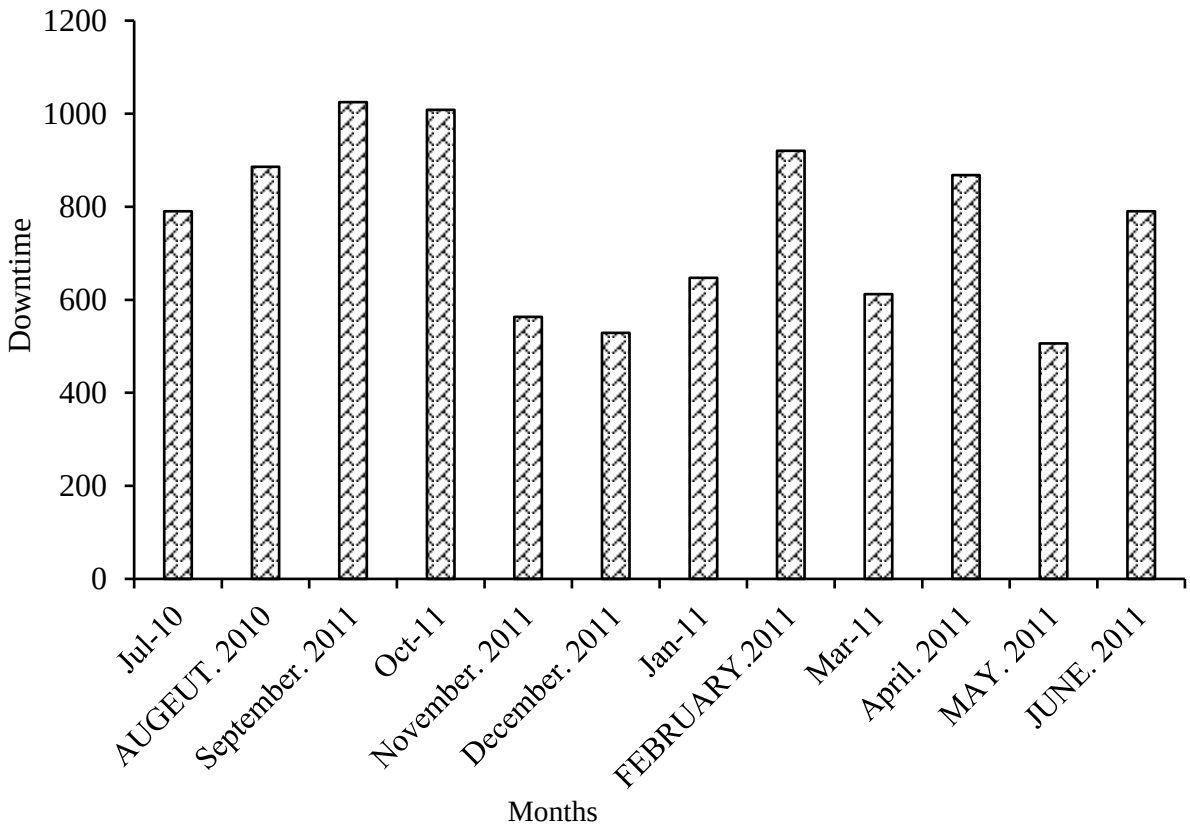

Figure 4.3. Total Truck Downtime (2011) E.C.

The specific area that represents the main cause of breakdown is shown on figure 4.4 and under the light repair maintenance was the specific area that to decrease productivities of 2011E.C year.

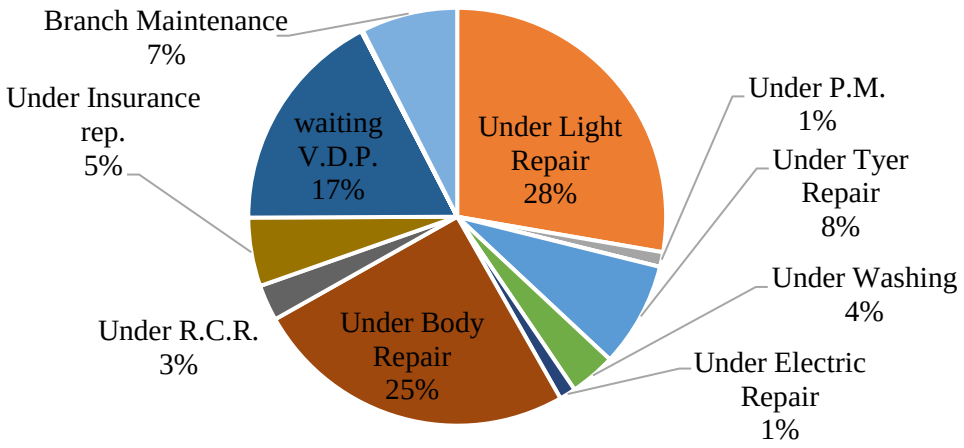

Figure 4.4. Total Truck Downtime Specific Area (2011) E.C

As figure 4.5 shown on July month breakdown maintenance was the higher value than the other months because of the maintenance under light group was higher than the other specific area maintenance section.

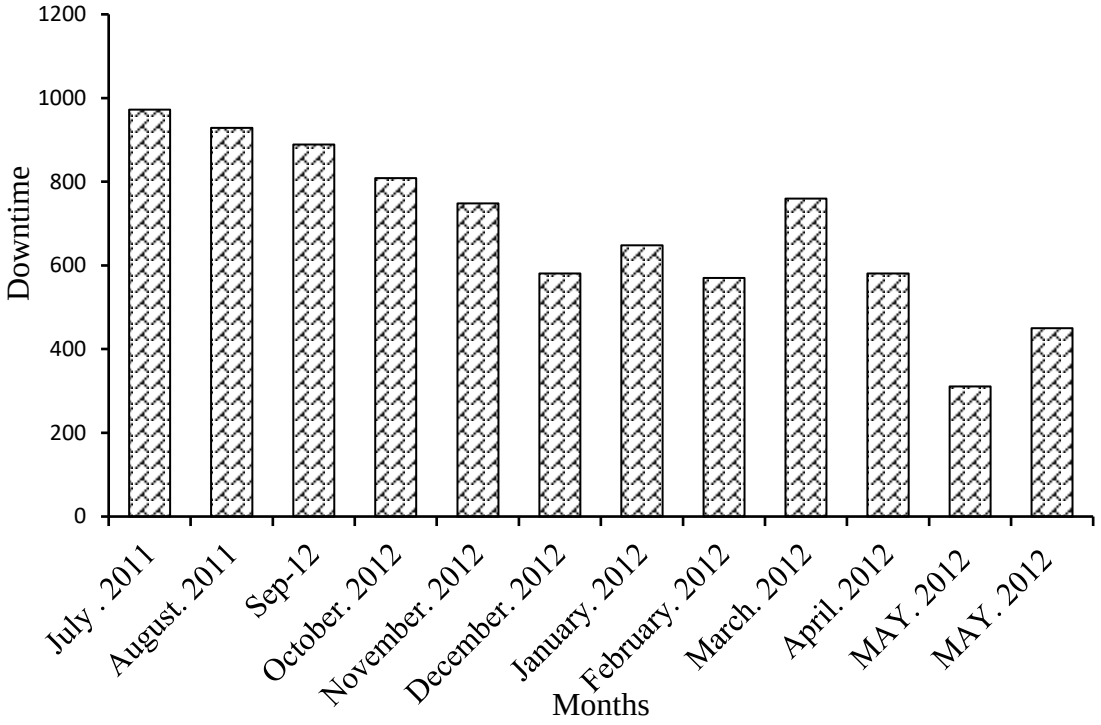

Figure 4.5: Total Truck Downtime (2012) E.C

figure 4.6 Under light maintenance section was greater than the other of maintenance specific area section according to the data that collected for analyze.

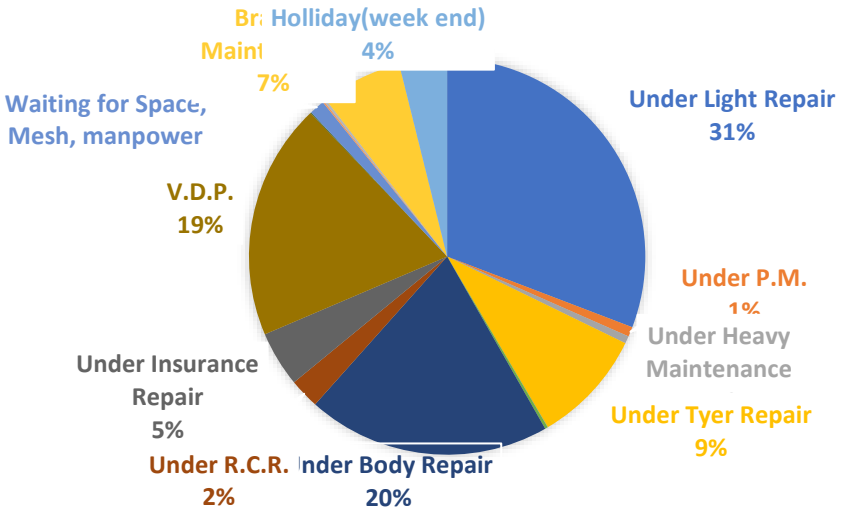

Figure 4.6. Total Truck Downtime Specific Area (2012) E.C

Figure 4.7 describe that the month February was the highest value of breakdown from the others months because of the maintenance under road call was the main problem of the breakdowns depending on the data collected that shown on the figure4.7.

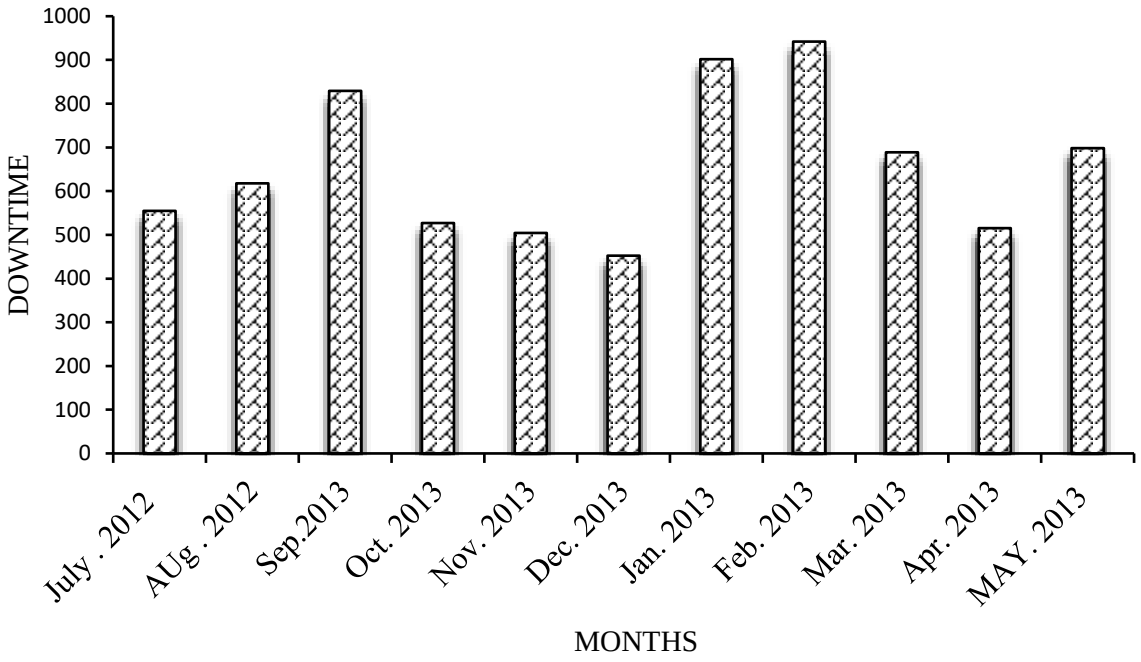

Figure 4.7. Total Truck Downtime (2013) E.C

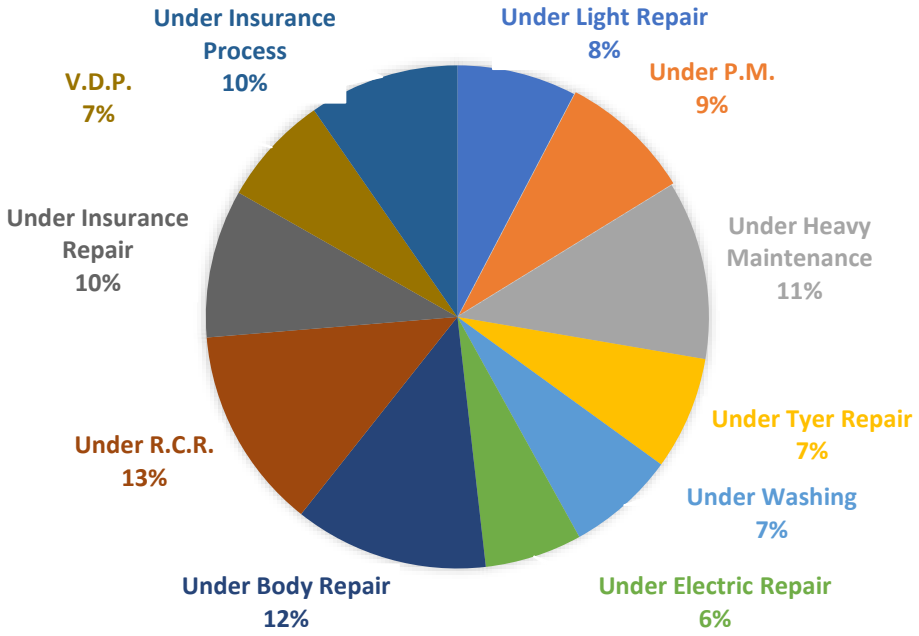

Figure 4.8. Total Downtime Specific Area (2013) E.C

Truck Performance is expressed in terms of overall equipment effectiveness (OEE).

OEE is calculated as;

$$OEE = Availability * Performance * Quality$$

12 months' data from June, 2012 up to June, 2013 taken to calculate OEE for 215 Trucks. Table is attached on Appendix A2. OEE of each Truck shown on Figure 4.9.

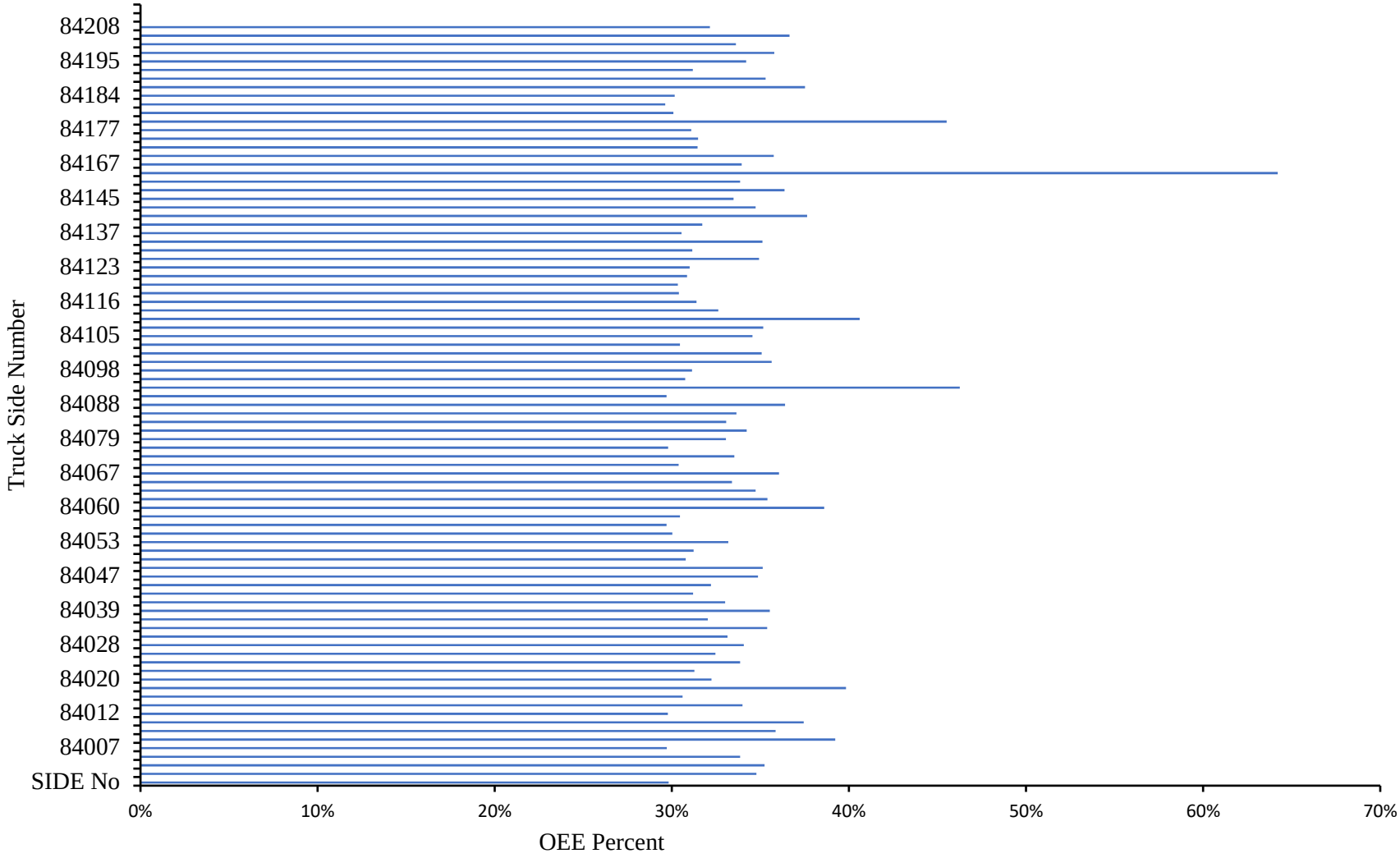

Figure 4.9. OEE of 215 Trucks 2013 E.C

4.2. Results of Documents

World class practice shows that the best practice OEE is 85%, but the highest values of Truckers are 64% OEE, As shown on Figure 4.9 OEE trend of all Truckers are almost the same. This is because of the maintenance that given under road call Repair. Since the production nature is continuous/linear, the rest of the Truckers governed by road call maintenance, under body repair maintenance & under heavy maintenance respectively.

4.3. Conceptual Framework of Maintenance Management

The results of the study the company has gaps on proactive maintenance, knowledge and skill on maintenance management and to perform maintenance activities, record keeping and documentation on maintenance activities and history. Over all, unavailability of holistic and standardized maintenance strategy frame work across the board the company follows.

Therefore, developed model at section 4.3.1 addresses above listed gaps.

4.3.1. Conceptual Framework

The developed conceptual framework for the case company is based on the identified gap in the data flow.

Set maintenance strategy: this will be determined directly from the business objective of the company and identifying maintenance strategy is very important to know the main role of maintenance department in the organization.

The objective includes:

- To insure the safe keeping of Trucks and equipment.
- To increase that Truck availability by 10% in 2023 (2015).
- Improve the skills and knowledge of the maintenance crew.
- Ensure the availability of spare parts and its quality.

Identify existing problem area: Overall equipment effectiveness (OEE) is an often-touted tool for managing a manufacturing operation. In its basic form, it is intended to identify production losses, primarily so that they can be managed, for example, planned and unplanned downtime, loss of speed and quality, or other losses and it is simple in concept, but much more difficult in practice, this is already indicated on Figure 4 .9.

Identify critical components of the bottle neck: Failure mode and effect analysis performed to identify critical components of Truckers.

Spare parts in maintenance operations

There are three different types of maintenance spare parts:

1. Rotables - These are items that constitute a sufficiently large subsystem of the original equipment to warrant a separate usage-based maintenance strategy.
2. Repairable - These are items that are repaired after replacement after which they are ready-for-use (RFU) again.
3. Consumables - These are items that are discarded after replacement and bought new from a supplier. generally, these are relatively cheap items such as gaskets based on researcher (Eindhoven & Version, 2021).

Repair shops and overhauls play a vital role in the supply chain of spare parts, as equipment maintenance is mostly carried out by replacing parts, self-repair and maintenance occurs mostly at the part level and is done in repair and overhaul shops. Performing the repair of parts is usually not standardized process because different parts of the same type may fail for widely varying reasons. Furthermore, repair shops often perform repairs for many different repairable types, consequently, repair and overhaul of spare parts is usually a labor-intensive process(Bousdekis et al., 2015).

Table 4.4: Common Failure of Spare Parts

Item No	Identification (Spare part)	Function	Functional failure	Failure mode	Effect	Preventive tasks	Default actions
1	Master cylinder	Applies Pressure to Brakes	1, Sinking Pedal 2, Contaminated Brake Fluid 3, Brake Warning Light 4, Check Engine Light 5, Low Brake Fluid	1, The structure is broken 2, The cylinder parts are damaged by impact, depression, scratches and corrosion.	1) Brake Fluid Leak 2) Spongy Brake Pedal 3) Contaminated Brake Fluid 4) Sinking Brake Pedal 5) Bad Brake Bias	1, Check Your Lubrication Levels 2, Check Your Oil Filters Check Your Cylinder Mountings and Accessories	1, Repair 2, Change
2	Clutch Disk	transmits engine torque directly to the input shaft of the transmission.	an incorrectly installed cover assembly; a lubricant contaminated clutch disc; incorrectly re- machined flywheels; or installation of the wrong clutch for the application.	1, Incorrect clutch applications 2, Driver abuse. 3, Improper/ inadequate clutch adjustment 4, Overloading of the vehicle.	clutch cover overheating, causing accelerated rates of clutch friction lining wear.	1, Check the refrigerant in the system 2, Check for a restriction in the system 3, Check the fan clutch or the fan assembly	Maintain/ Repair Change

Item No	Identification (Spare part)	Function	Functional failure	Failure mode(cause)	Effect	Preventive tasks	Default actions
3	Coolant Expansion tank	Storing coolant	1, Reservoir 2, Broken radiator Cap3, A faulty thermostat A clogged system	Corrosion Crack	Leaking coolant Overheating Rusty radiator	Check **C**oolant level Change coolant	Replace
4	Leaf spring	absorb the vehicle vibrations, shocks and bump loads	spring defect, installation problem or overload	Crack Broken	Can reduce performance and function of leaf spring assembly and lead to serious accidents.	Choosing good Way Reduce load	Replace
5	Servo Clutch	a pneumatically-assisted clutch-actuation device, enabling accurate	worn out friction disc of pressure plate that has lost its tension.	Contamination Bearing failure Brake failure Over heating	clutch doesn't engage fully, slips under heavy load,	Take your foot completely off the clutch. Avoid holding, Accelerate and decelerate smoothly	Repair change
6	Gear Box	Transmitting energy in a mechanical engine to increase		Lubrication Arrangement Abrasive wear Breakage	Transition not occur properly	Following Preventive maintenance	Repair

7	ABS	to protect the vehicle's wheels not lock when you apply sudden braking.	Sensors Controller Break pump	Wear Over heating	Accident happens by cause of this	Checking & inspecting according to module	Change
8	Tire	Support loads, reduce shock absorber, Direction, Acceleration & backing	Tire Tube damaged Tire Wire damaged	Over load Choosing the wrong way of driver	Happen accident Load to be dropped at that side	Choosing good Way Visual inspection	Repair Change
9	Shackle	Supporting & Carrying The load	Pin& pin hole damage, Cracking in edges	Over load Choosing the wrong way of driver	Load to be dropped at that side	Choosing good Way Reduce load	Change Repair

Select maintenance strategy: tacit and explicit knowledge used due to incomplete data (Lundgren et al., 2018). Based on the discussion with technical experts' preventive maintenance is selected for Truckers with the rational of its dominance on the performance of the Trucker. in addition to that autonomous maintenance is best for the company because of available manpower in the department and autonomous maintenance preferred to conduct preventive maintenance. Because autonomous maintenance empowers operators to minimize response time and perform productive maintenance this aims to improve the maintenance skills and knowledge among shop floor operators. It also improves Truck availability through better utilization of maintenance and production resource. In addition, this also free the maintenance staff to specialize on specific maintenance system to perform more and more on planned maintenance.

Workflow system: is the information system for the maintenance organization very important for the success of the job (Bakri et al., 2020). since there is no standard work flow, new workflow proposed on figure 4.9. this must be followed by the maintenance scheduler. Without a commitment to recording all maintenance activities in a work order, an organization does not have the data to perform any meaningful analysis of its policies and procedures, or more importantly, the equipment it is responsible for. Moreover, without a workflow system, it is not possible to plan and schedule maintenance activities.

Work orders raised by operation department & inspectors fill work order request form and approve by his/her own without department manager authentication and submit to maintenance Forman's. work orders raised by inspectors is good b/c of he/she fill tag and put on that specific area. Therefore, planner will organize work orders from work order request format and tags. Based on the dead line and urgency works will generate prepare spare parts, allocate manpower and required time to complete the job. nest work orders released to executers, during execution maintenance planners has to follow the progress and quality of work. After completion Inspector validate or confirm that the maintenance activity is successful. This can measure by reworks. The last stage is recording keeping. It helps to build Truck histories, measuring performance, helps for decision making purpose also.

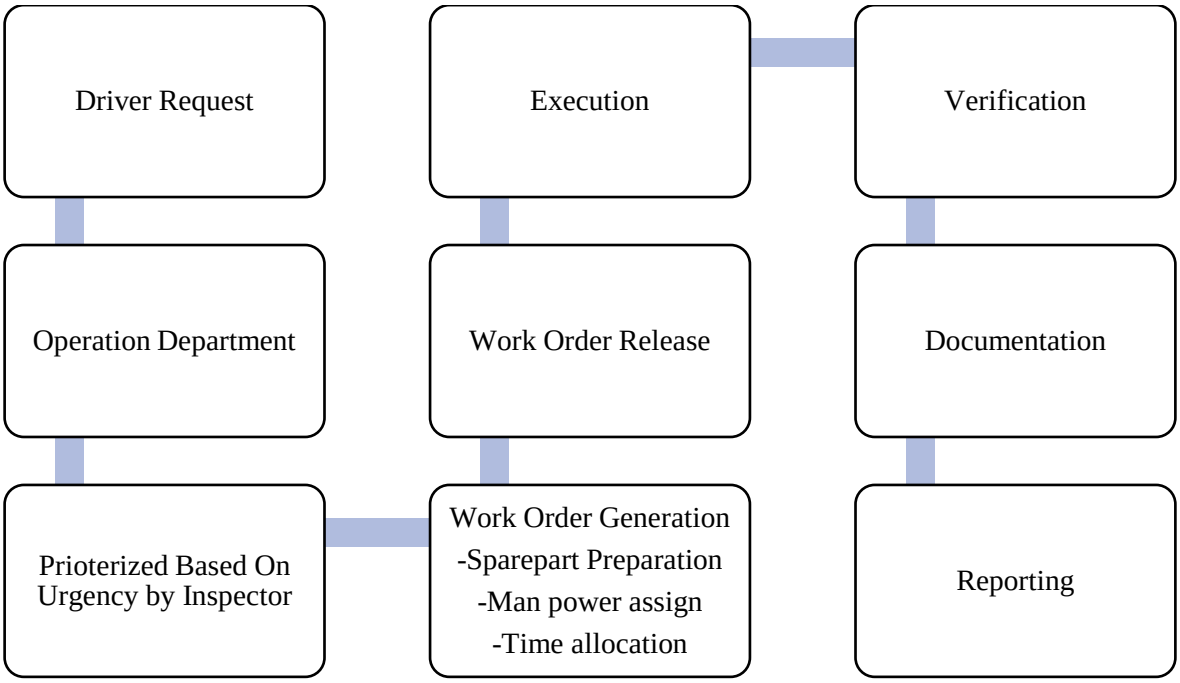

Figure 4.10. proposed workflow

Computerized maintenance management system:

Developed Computerized maintenance management system is faster and easier to collect data and then manipulate that data into a meaningful report format. Every information of Spare part of store, Truck breakdowns, time taken to technician, performance of technician in all every Analysis in workshop activities, in general, company will be much benefited, especially in recording and documenting the necessary information, if they install it.

Trucks menu is that helps to record all activities concerning the Trucks under maintenance. In this menu; workorder number, truck side number, Truck type, Date, description of work, time taken for the task and Time allowed will be recorded.

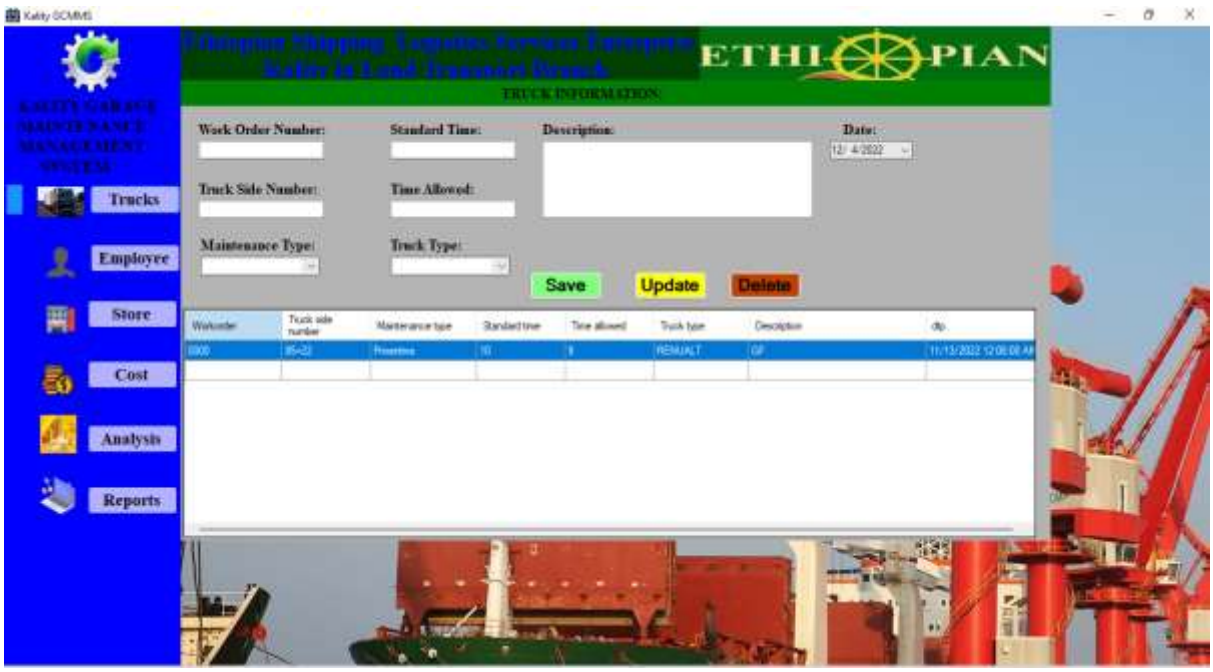

Figure 4.11. Truck Information Menu: developed by authors (Researcher)

Employee menu, this helps to enter the information about the employee, who is doing or going to do the work. Thus, the necessary information concerning the employee will be recorded and so the planner or the supervisor can easily understand who is capable to assign the work.

Figure 4.12. labor information Menu: developed by authors (Researcher)

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

Figure 4.13. Store information Menu: developed by authors (Researcher)

Cost menu helps to record the information about the Total cost. It has the entity bars for the spare part cost, labor cost, other cost & Total cost. The figure below shows the program parts menu interface.

Figure 4.14. Cost information Menu: developed by authors (Researcher)

Analysis menu: Mobility Work provides with another dashboard in order to make the best decision, which gathers information such as Trucks, spare parts, Labor and determine the total cost of intervention on maintenance.

Figure 4.15 Analysis Menu: developed by authors (Researcher)

Report Menu: under this menu all of activities are collected by the program as word, Excel, Pdf and reported to authorized persons.

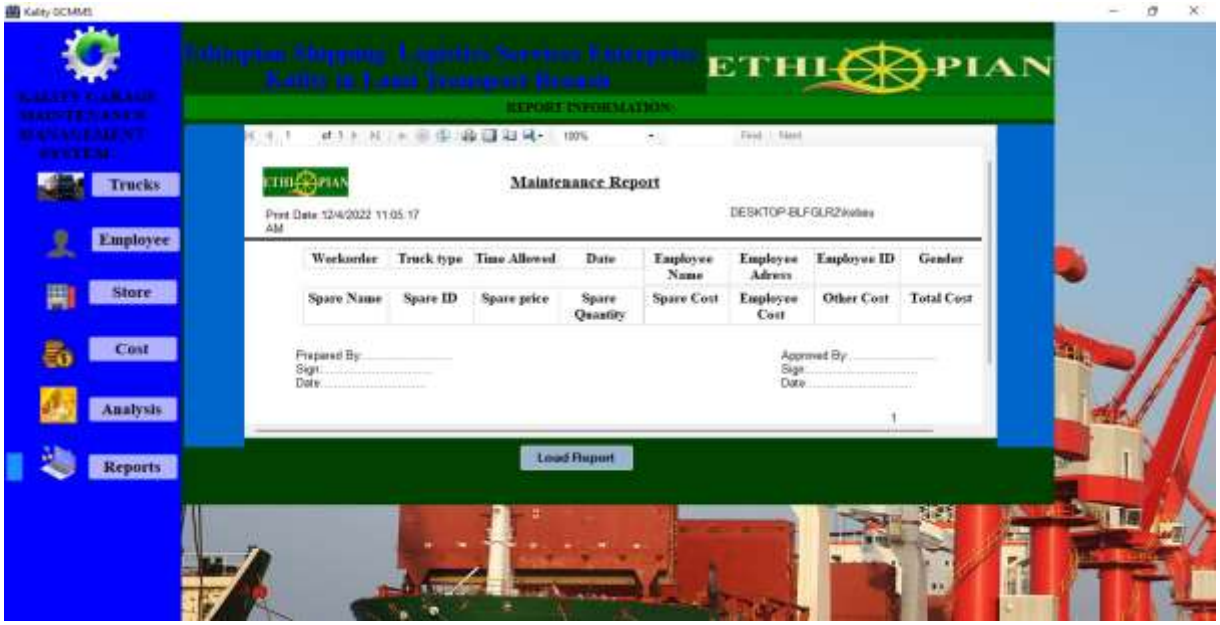

Figure 4.16: Report Menu: developed by authors (Researcher)

Set key performance indicators: selected performance indicators listed below. The indicators derived from maintenance objective

- Unplanned downtimes.
- Percentage of maintenance work order completed.
- Number of practical trainings given for succession plan
- Percentage of maintenance work orders requiring rework

Table 4.5: Proposed KPI

KPI Measurements	**Measurement** In %	**Weight (%)**	**Target**
Un planed downtimes		30	>=5%
PM conducted according to the checklist / PM schedule Compliance		5	100%
Percentage of maintenance work orders completed within the specified period		20	85%
Percentage of maintenance work orders requiring rework		15	This level should not exceed 2 to 3% b/c of world value limit
percentage of work orders assigned 'Delay' status due to unavailability of manpower, equipment, space or services over the specified time period		20	This number should not exceed 3 to 5% b/c of world value limit
Number of practical trainings given for succession plan		10	100%

Continuous improvement: after measuring the performance, the result will lead for potentially improved areas such as setting objective, identifying most important system and its critical component, maintenance strategy, work flow system, Garage MMS or performance indicators. Therefore, by following this cycle there is always an improvement on the maintenance management system. For example, When the business objectives are changed, the measurement system should be changed accordingly. Failing this, the measurement system cannot be used to control the strategically important success factors. Proposed framework will benefit the company by placing a system to increasing Truck performance, reducing down time.

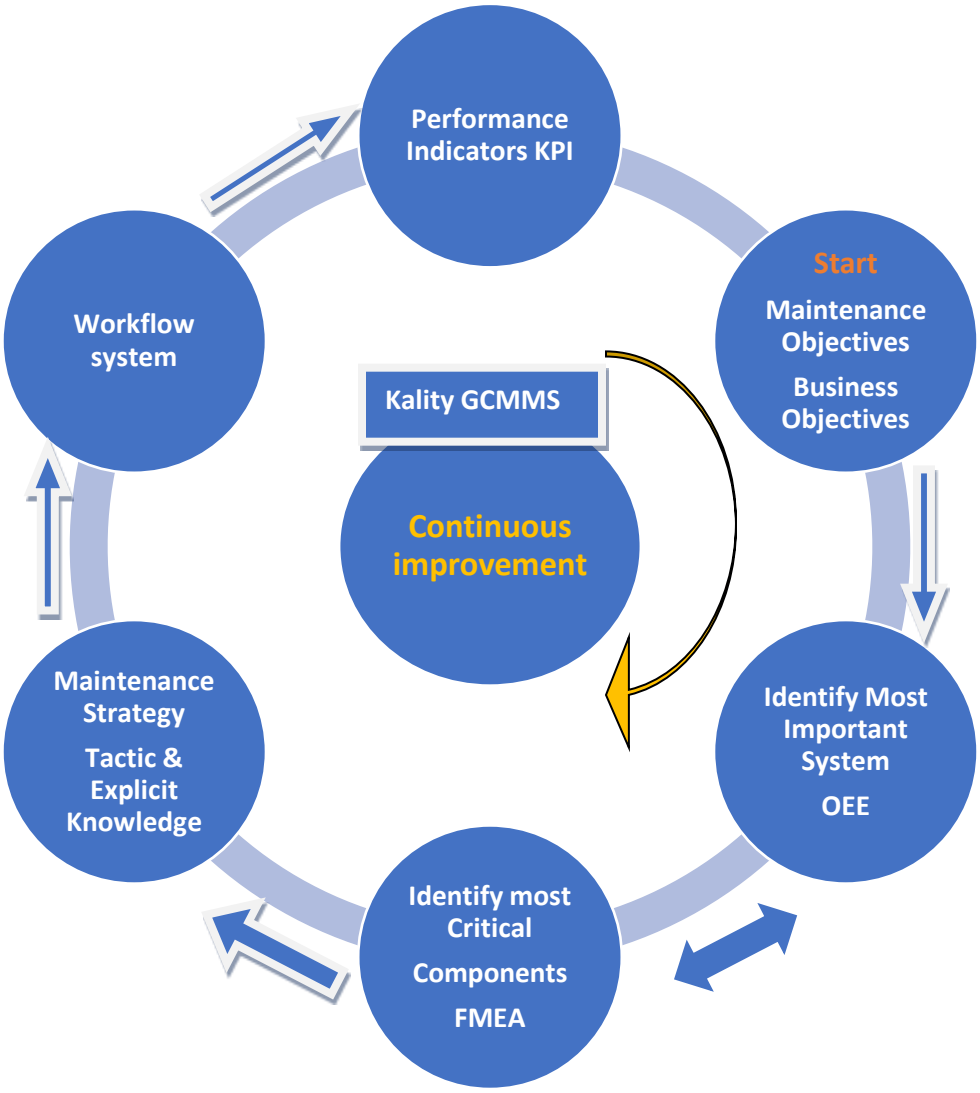

Figure 4.17: Proposed Conceptual framework of maintenance management

4.5. Implementation procedure

A certain step needs to be followed during implementation.

1. Briefing and convincing top management about the importance of maintenance function for the company success.
2. Form a team from different background.
3. Provide training for the team on:
    - What is the business objective of the company?
    - What contributes most to the company's success?
    - What is the maintenance objective?
    - What are the types of maintenance strategies with their advantages and limitations?
    - Tools and techniques that can be used for failure analysis?
4. The selected team will begin the implementation of the maintenance management framework.
    - Set maintenance strategy.
    - Identify systems by using OEE.
    - Identify critical components by doing FMEA.
    - Select maintenance strategies to be followed.
    - In place workflow system.
    - Set KPI for each position at maintenance department.
    - Conduct information recording formats for the performance indicators to make KPI evaluation accurate.
    - Improve the system continually based on the performance.

4.6. Validation

Because of time constraint validation of the frameworks done by discussion in a meeting with the presence of plant manager, maintenance manager and technical experts. during discussion, raised points include relevance of the framework, feasibility of framework, in what area may the framework has to be improved and discussion framework is relevant and feasible because of it addresses practical problems. it requires develop workflow, checklist is recommended to incorporate on the workflow, because checklists can be also source of work order generation. in addition to this exhaustive training of all maintenance department required to implement maintenance management system effectively and efficiently.

Chapter -5

5. Conclusion and Recommendation

5.1. Conclusion

In developing countries, taking maintenance as a core business function is at an infant stage, this conclusion is taken because, maintenance was taken as a cost center and the number of studies is very limited. In this study Ethiopian Shipping and Logistics Service Enterprise Kality branch is selected as a case, Literatures reviewed intensively on maintenance strategies, maintenance management models, performance measurements, for this research maintenance frameworks reviewed. both empirical and theoretical gaps identified and incorporated on developed framework. based on the study case company, Road Call Repair is a bottle neck of the company Objectives. The company has limitation of focus on proactive maintenance strategies, record keeping and documentation on maintenance activities and history, knowledge and skill gap Training on how to maintain a Trucks, also Training how to use maintenance tools and techniques and over all, unavailability of holistic and standardized maintenance strategy frame work across the board the case company follows. The framework has 8 building blocks cycles, it starts by setting maintenance objectives, the objective is derived from business objective of the company. The second building block is determining the system and OEE used to determine the system per the result two sub systems identified. The first system is a bottle neck to the whole system, therefore by using FMEA major failure modes identified. The next building block is choosing maintenance strategy, this is done by using tactic and explicit knowledge of the experts and the method is chosen because of data unavailability. Fifth building block is a proposing a work flow system in order to have uniform or standard workflow for maintenance activities. The sixth block is identifying performance indicators as per maintenance objective and the seventh building block is continuous improvement, after measuring the performance improvement areas will be revealed. To address improvement areas, the cycle will continue, all these seven building blocks are integrated by computerized maintenance management system. This Kality Garage CMMS will have necessary information to measure the performance and generating accurate and relevant reports in no time. It is also important to develop Truck history which is relevant to prepare maintenance plan and other decision making. Building block five and seven addressed identified theoretical gaps, validation of the framework done by discussion in a meeting with technical team.

5.2. Recommendation

Based on the result of the above study the case company recommended to take below listed measures in order to become effective and efficient on maintenance activities, this also maximize production output.

- Implement a maintenance framework in the company to reduce downtime.
- Take action for Road Call Repair with higher capacity.
- Install Kality Garage CMMS Software to have better communication inside the department in order to monitor pending jobs, spare part management, save time to generate sound and accurate relevant reports.
- Upgrade maintenance staff's knowledge on key performance indicators by exercising at lower level in terms of reports.
- Maintenance should be an organizational policy as one of the strategies in being productive and competitive. And the department should be given emphasis, as it is one of the main areas for productivity improvement. The developed maintenance workflow system in this paper is recommended for them to be effective.
- Maintenance awareness and commitment should be created in the companies starting from the top management in the organizations up to the lower level through training and seminars.
- Companies should encourage their operator to become familiar with the machines they operate. Training should be provided for them to acquire:
  - The ability to detect equipment abnormalities and make improvement,
  - The ability to understand equipment functions and mechanisms, and the ability to detect causes of abnormality
  - The ability to understand the relationship between equipment and quality
  - The ability to make repair

5.3. FUTURE WORK

As previously described in the thesis, maintenance organizations concentrated mostly on developing new models and optimizations of the current maintenance strategies and the thesis also describes trends in production at current. This thesis presents on the key factors for fourth generation of maintenance and the emerging trends and challenges in production to be faced in future.

1. Model for the future generation maintenance considering the key factors

Many organizations are comfortable with the third generation of maintenance. The future research should focus on the future maintenance model considering the proposed factors. The importance given to each factor, while considering the effective planning and implementing of maintenance.

2. Integrated production maintenance approach

The total productive maintenance approach enables the relationship between maintenance and production. Considering the proposed key factors for future generation of maintenance and future trends of production, an integrated model for maintenance starting from the equipment design to its whole life cycle should be concentrated in the study.

3. Maintenance as a “competitive factor”

So far, the first-generation maintenance is considered as “necessary evil”, but as the development of maintenance and its importance are growing, maintenance is to be considered as a “competitive factor”, which helps the organization to grow more competitive with other organizations. The study should concentrate on developing maintenance and presenting more effective environment.

4. Effective sustainable production

As the importance of sustainability is growing and it is considered to be necessary in production. The study should be able to demonstrate the value of sustainable production by studying history of sustainability and its integration in production. The study should also focus on the impacts of sustainability both in production and organization.

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Appendix A Questionary

Section 1: Demographic characteristics

Please, choose the suitable answer and tick in the box given for each question.

1. Gender 1 Female ☐ 2 Male ☐

2. Age 1. 20 – 35 years ☐
   2. 36 – 49 years ☐ 3. 50 – 60 years ☐
   4. Above 60 years ☐

3. Education qualification;
   1. Diploma ☐ 2. Degree ☐
   3.Masters ☐ 4. PhD & above ☐

4. work experience
   0-5 ☐
   6-10 ☐
   11-15 ☐
   16-20 ☐
   Above 21 ☐

Section 2: Maintenance Department

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

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

S. N	**Maintenance Department**	5	4	3	2	1
1	Supervisors & leader possessed adequate technical skills.					
2	The management encourage maintenance to meet the needs of Production.					
3	The management support maintenance technicians and work together on problems.					
4	Maintenance technicians follow safety policies and procedures when they do their tasks.					
5	The industry support to continuous improvement efforts.					

Section 3: Maintenance Planning & scheduling

S. N	**Maintenance Planning and Scheduling**	5	4	3	2	1
6	The total amount of work orders has been delayed due to poor or incomplete plans.					
7	The equipment's are maintained within a short time when the equipment's failed.					
8	You have appropriate spare parts for maintenance.					
9	Training concerning new technologies are provided frequently to the maintenance craft employees at your Company.					
10	Scheduled training programs are given on maintenance.					
11	The organization use work orders for preventive maintenance activities.					
12	The organization has track record how much it costs (Life Cycle Cost) to maintain equipment.					
13	The organization have a schedule for periodic preventive maintenance.					
14	The organization has an inspection team to check the actual condition of equipment.					

Section 4: Maintenance Analysis Department

S.N	**Maintenance Inventory and Purchasing**	5	4	3	2	1
15	There is an availability of critical spare parts in the store.					
16	There is an indicator of maximum and minimum levels for specified stored materials.					
17	There is a permanent supplier of spare parts.					

18	There is failure analysis conducted by the use of an analysis tool such as fishbone, tree, five why's or Pareto, to assure accuracy and standardization for each analysis.					
19	There is overall equipment evaluation calculated to monitor the condition of critical equipment.					
20	The Trucks/machines perform their required function for the specified time.					
21	The organization believe that improving maintenance could increase the reliability of production system.					

Section 5: Maintenance Staff

S.N		5	4	3	2	1
22	The production/Trips focus on maintenance practice.					
23	Stoppage of production (Trip) has a huge impact on the organization.					
24	Truck downtime reduces designed or planned production capacity.					
25	The level of Truck/machine downtime affects total production time.					
26	In your company unexpected maintenance cost happens highly.					

27. What causes Truck breakdown

- ☐ 1. Lack of proper maintenance system
- ☐ 2. Quality of spare part
- ☐ 3. Shortage of required spare parts
- ☐ 4. Unavailability of required tools and equipment's
- 5. Lack of skilled manpower
- 6. Lack of training of technical team

☐ 7. Lack of employee commitment

☐ 8. All & if Others, please mention

_____

_____

_____

28. What type of maintenance strategy do you follow in your assigned area?

☐ 1. Preventive maintenance

☐ 2. Corrective maintenance

☐ 3. Breakdown maintenance

☐ 4. Predictive maintenance

29. What method do you use to record maintenance records?

☐ 1. Computer based maintenance management system

☐ 2. Spreadsheet

☐ 3. Manual paper recording

Appendix A1 Operational Downtimes

2011 E.C በጀት ዓመት የባከኑ ቀናትና ተሽከርካሪ ብዛት(Opration Downtime)

	የጊዜ ብክነት ምክንያት	የባከነ የተሽከርካሪ ቀናት እና በሠንጠረዡ የተሽከርካሪ ብዛት የሚገልፅ ዝርዝር መግለጫ													
		1	2	3	4	5	6	7	8	9	10	11	12	14-39	ድምር
ተ.ቁ	**ጅቡቲ ውስጥ**														
1	ሚሌ ላይ ሳያስመዘግቡ ጅቡቲ የገቡ	25	51	66	16	2									**160**
2	ጌትፓስ በማውጣት ሂደት	4	11	91	31	2									**139**
3	የኤክስፖርት ጭነት ለማራገፍ		10	9	9	2									**30**
4	ጭነት ለመጫን ወረፋ	7	50	51	4	9	2								**123**
5	ሐሙስ ጌትፓስ ስለማይወጣ		4	57	43		2								**106**
6	በሲስተም ምክንየት		5	12	3	5									**25**
7	በጉምሩክ ዶኩመንት	1	4	19	9			1							**34**
8	ባ/ዶ ለማራገፍ	45	44	19	15	3	1							1	**128**
10	ኢሚል በወቅቱ አለመድረስ														**0**
11	በሲል ምክንያት			2											**2**
12	በኮንቴይነር ቁጥር ስህተት														**0**
13	በበዓል ምክንያት	1	7	6											**14**
14	በአደጋ ምክንያት														**0**
15	በጎርፍ ምክንያት		8	5	2										**15**
	ድምር	**83**	**198**	**348**	**134**	**27**	**5**	**1**	**0**	**0**	**1**	**0**	**0**	**2**	776

	የጊዜ ብክነት ምክንያት	በበጀት ዓመቱ የባከኑ ቀናትና ተሽከርካሪ ብዛት 2012 E.C													
		1	2	3	4	5	6	7	8	9	10	12	14	19	ድምር
	ጅቡቲ ውስጥ														
1	ጌትፓስ በማውጣት ሂደት ለ MTS ሪፖርት ከተደረገ በኃላ ትራንዚተሮችን በዱቤ ከማሰራቱ ጋር በተያያዘ ቁጥጥር ለማድረግ በመቸገሩ የተፈጠረ መዘግየት	8	3	121	77	19	12	3		2					245
2	የኤክስፖርት ጭነት ለማራገፍ		2	10	8	4	2	2							28
3	ጭነት ለመጫን ወረፋ ጥበቃ	10	6	85	74	42	14	2							233
4	በሲስተም እና ሲል ምክንየት			1		2	1				1				5
5	በጉምሩክ ዶኩመንት			98	47	48	7	8	3	2	1	1			215
6	ባ/ዶ ለማራገፍ			26	9	10	3	1	1						50
8	በሲል ምክንያት			2		1				2	1		1		7
9	ሹፌር ህመም				1										1
10	ሀሙስ ጌትፓስ ስለማይወጣ			16											16
11	በበአል ምክንያት		42	2	4	8									56
12	በአደጋ ምክንያት				1						1				2
13	ጭነት እጥረት			3											3
14	ባዶ ቀረጢት ለማራገፍ			1					1		1		1		4
	ድምር	23	54	374	228	136	43	16	6	7	8	3	3	1	865

2012 E.C በጀት ዓመት የባከኑ ቀናትና ተሽከርካሪ ብዛት(Operational Downtime)

2013 E.C በጀት ዓመት የባከኑ ቀናትና ተሽከርካሪ ብዛት(Operational Downtime)

ተ.ቁ	የጊዜ ብክነት ምክንያት	በበጀት ዓመቱ የባከኑ ቀናትና ተሽከርካሪ ብዛት														
		1	2	3	4	5	6	7	8	9	10	11	12	14	18	ድምር
	ጅቡቲ ውስጥ															
1	ጌትፓስ በማውጣት ሂደት	82	79	39	3	5	3	1						1		**213**
2	የኤክስፖርት ጭነት ለማራገፍ		11	18	7	5					1	1				**43**
3	ጭነት እጥረት	71	64	9	5	1	1	1		1	1			1		**155**
4	ማሽን ችግር በመጫን ወረፋ		26	10	8	3	2									**49**
5	አዲስ መኪና ሂደቱ እስከሚያልቅ የቆየ				1	44	6	17	**12**	6	8	5	1			**100**
6	ሐሙስና አርብ ምደባ ባለመኖሩ		10													**10**
7	ከማበዳሪያ ወደ ኮንቴነር የዞረ		1		3											**4**
4	በኢንሹራንስ ምክንያት			1	1		1	1							1	**5**
5	በሲስተም ምክንየት		4	3	4											**11**
6	በጉምሩክ ዶኩመንት	8	15	6	7	3										**39**
7	ባ/ዶ ለማራገፍ	28	13	7	2		1									**51**
9	በሹፌር ህመም ምክንየት			1												**1**
10	ሬንጅ በመጫን ሂደት		2	4												**6**
ድምር		**194**	**228**	**103**	**42**	**64**	**16**	**21**	**13**	**7**	**11**	**7**	**1**	**2**	**1**	**668**

Appendix A2 Maintenance Downtimes

Table. Downtime Renault Truck 2011

	july 2010 e.c	AUGEUT. 2010	septemb er. 2011	october 2011 e.c.	novemb er. 2011	decemb er. 2011	january 2011 e.c.	FEBRUA RY.2011	March 2011 e.c.	April. 2011	MAY. 2011 E.C.	JUNE. 2011 E.C.
Under Light Repair	219	266	255	326	190	223	202	362	211	292	162	302
Under P.M.	9	12	11	15	4	3	4	14	5	4	4	7
Heavy	0	0	0	0	0	0	0	24	53	42	17	33
Tyer Repair	64	63	72	63	52	28	24	89	32	53	73	153
Under Washing	28	29	25	18	8	10	1	0	0	1	1	0
Electric Repair	10	18	8	5	3	3	0	4	1	0	3	5
Body Repair	198	222	333	279	73	61	76	178	119	107	71	146
Under R.C.R.	22	2	10	17	5	11	26	22	10	3	5	11
Under Insurance	42	56	76	58	8	0	0	16	10	0	0	0
waiting V.D.P.	138	99	98	114	156	132	198	137	140	309	114	97
Under Insurance proc.	0	0	0	0	0	0	0	0	0	0	0	0
Waiting for Decision	0	0	0	0	0	0	0	0	0	0	0	2
Waiting manpowe	1	1	28	20	0	0	0	17	10	20	1	0
Trailer Repair	0	0	0	1	0	2	0	0	0	0	13	0
Others	0	0	0	0	0	4	0	0	0	0	0	1
Branch Maintena nce	59	103	83	68	64	52	88	57	21	37	21	33
Holliday	0	15	23	24	0	0	28	0	0	0	21	0
TOTAL DOWN TIME	790	886	1025	1008	563	529	647	920	612	868	506	790
												9145

Table. Downtime Renault Truck 2012

Under R.C.R.	17	11	21	27	10	5	14	6	19	24	33	13	200
Under Insurance Repair	0	47	75	67	50	54	28	2	42	0	0	4	369
V.D.P.	200	238	226	121	250	84	204	40	102	18	15	76	1574
Under Insurance Process	0	0	0	0	0	0	0	0	0	0	0	0	0
Waiting for Decision	6	0	0	0	0	0	0	0	0	0	0	0	6
Waiting for Space, Mesh, manpower	0	0	10	0	0	0	4	2	6	75	1	4	102
Trailer Repair	0	0	0	9	0	0	0	1	0	0	0	0	10
Others	0	0	1	0	0	0	0	0	1	13	0	1	16
Branch Maintenance	29	45	31	49	52	49	36	36	71	37	47	55	537
Holliday(week end)	32	0	31	82	68	45	48	0	0	11	0	0	317
	972	929	889	809	748	581	648	570	760	581	311	450	8154

Table. Downtime Renault Truck 2013

	July . 2012 E.C.	AUg . 2012	Sep.2013 e.c.	Oct. 2013	Nov. 2013	Dec. 2013	Jan. 2013 e.c.	Feb. 2013 e.c.	Mar. 2013	Apr. 2013	MAY. 2013 E.C.	Total DownTime
Under Light Repair	144	162	242	169	171	160	348	388	283	212	234	2513
Under P.M.	3	1	0	2	1	5	12	5	7	3	5	44
Under Heavy Maintenance	16	2	7	3	14	0	2	2	13	0	34	93
Under Tyer Repair	35	23	64	16	11	13	55	78	37	30	31	393
Under Washing	0	0	9	4	0	0	3	0	0	0	0	16
Under Electric Repair	2	5	5	2	4	0	1	6	4	1	3	33
Under Body Repair	158	138	281	132	140	159	285	278	166	156	130	2023
Under R.C.R.	41	57	44	53	29	11	2	15	31	18	11	312
Under Insurance Repair	10	75	11	34	9	3	2	3	0	0	23	170
V.D.P.	39	52	59	33	47	48	49	73	89	35	33	557
Under Insurance Process	0	0	0	0	0	0	0	0	0	0	0	0
Waiting for Decision	0	0	0	0	0	0	0	10	3	0	4	17
Waiting for man power	1	2	6	2	0	0	25	5	5	0	3	49
Trailer Repair	0	0	0	0	0	0	0	0	0	0	0	0
Others	0	0	0	0	0	0	0	3	11	0	1	15
Branch Maintenance	106	101	77	77	78	53	37	76	40	12	68	725
Holliday	0	0	24	0	0	0	81	0	0	48	118	271
	555	618	829	527	504	452	902	942	689	515	698	7231

Appendix B Annual Vehicle Performance Report& OEE Table

		Ton KM (in Mil.)				Defect			Truck Days							
SIDE No	Potent.	Actual	Round	Oper.	Garag.	W/load	Road call	Accid't	Freight	Other	Total	DT	Actual	Performance	Quality	OEE
84001	2.54	1.441375	2.41	154	39	44	16	2	7	1	365	58	84%	57%	71%	34%
84002	2.66	1.520075	2.52	153	53	55	11	0	0	4	365	68	81%	57%	64%	30%
84003	2.28	1.243753	2.16	145	47	44	32	6	7	5	365	90	75%	55%	70%	29%
84004	2.41	1.342758	2.28	149	45	33	27	0	0	1	365	73	80%	56%	78%	35%
84005	2.22	1.183647	2.1	130	56	40	11	18	11	3	365	88	76%	53%	69%	28%
84007	2.57	1.464873	2.43	166	30	40	17	0	13	21	365	68	81%	57%	76%	35%
84008	2.3	1.28377	2.18	139	56	26	27	3	0	7	365	93	75%	56%	81%	34%
84009	2.19	1.210777	2.08	131	64	41	12	0	0	3	365	79	78%	55%	69%	30%
84010	2.04	1.158819	1.93	117	82	67	21	0	0	5	365	108	70%	57%	43%	17%
84011	2.57	1.46846	2.44	178	33	35	14	1	4	5	365	53	85%	57%	80%	39%
84012	2.44	1.381152	2.31	147	63	26	13	0	15	8	365	84	77%	57%	82%	36%
84013	2.33	1.301118	2.21	138	34	48	43	0	0	0	365	77	79%	56%	65%	29%
84014	2.5	1.355212	2.37	151	63	51	13	0	0	12	365	88	76%	54%	66%	27%
84015	2.17	1.28407	2.06	151	46	28	22	0	22	13	365	81	78%	59%	81%	37%
84016	2.29	1.26454	2.17	133	74	35	24	0	6	0	365	98	73%	55%	74%	30%
84018	2	1.117834	1.89	134	66	55	23	1	0	13	365	103	72%	56%	59%	24%
84019	2.4	1.34477	2.27	158	67	30	17	0	19	8	365	92	75%	56%	81%	34%
84020	2.37	1.29179	2.24	136	50	40	15	0	11	10	365	75	79%	55%	71%	31%
84021	2.87	1.591659	2.72	175	41	30	7	0	0	0	365	48	87%	55%	83%	40%
84022	2.47	1.454932	2.34	140	45	54	15	0	0	29	365	89	76%	59%	61%	27%
84023	2.31	1.278794	2.19	147	55	32	15	10	7	13	365	93	75%	55%	78%	32%
84024	2.12	1.173845	2.01	131	68	21	30	1	5	21	365	120	67%	55%	84%	31%
84025	1.89	0.990903	1.79	124	70	39	29	0	8	10	365	109	70%	52%	69%	25%
84026	0.89	0.471135	0.84	58	49	27	13	0	0	173	365	235	36%	53%	53%	10%
84028	2.42	1.368969	2.29	144	39	37	20	0	6	12	365	71	81%	57%	74%	34%
84029	2.29	1.264795	2.17	137	46	48	20	2	5	4	365	72	80%	55%	65%	29%
84030	2.38	1.341842	2.26	140	54	60	16	0	0	14	365	84	77%	56%	57%	25%
84031	2.23	1.271502	2.11	154	55	43	14	0	12	8	365	77	79%	57%	72%	32%
84032	2.13	1.40143	2.01	128	61	33	16	20	0	14	365	111	70%	66%	74%	34%

84059	1.987	1.13178	1.8836	129	101	28	18	0	7	14	365	133	64%	57%
84060	2.346	1.28279	2.2238	143	51	41	23	0	0	13	365	87	76%	55%
84061	2.459	1.40947	2.3308	142	45	52	13	0	4	1	365	59	84%	57%
84063	2.559	1.47067	2.4251	177	28	41	14	0	8	4	365	46	87%	57%
84064	2.441	1.44766	2.3132	144	49	20	23	30	3	10	365	112	69%	59%
84065	1.579	0.85452	1.4964	87	71	23	34	67	0	9	365	181	50%	54%
84066	2.167	1.21517	2.0537	130	86	43	23	0	0	10	365	119	67%	56%
84067	2.27	1.28964	2.1513	158	43	33	27	0	9	13	365	83	77%	57%
84068	2.204	1.1999	2.0894	136	47	28	36	0	11	0	365	83	77%	54%
84069	1.989	1.16514	1.8853	123	74	40	37	10	8	3	365	124	66%	59%
84070	2.212	1.26938	2.0962	129	65	57	28	0	0	9	365	102	72%	57%
84071	2.146	1.23396	2.034	138	56	55	10	0	19	8	365	74	80%	57%
84072	1.269	0.72647	1.2024	98	43	38	23	0	9	96	365	162	56%	57%
84073	2.646	1.53994	2.5077	161	24	49	16	0	8	0	365	40	89%	58%
84074	1.957	1.48928	1.855	124	74	52	20	1	0	19	365	114	69%	76%
84075	1.576	0.88371	1.4935	135	35	33	12	0	2	94	365	141	61%	56%
84076	1.519	0.80192	1.4396	101	49	25	11	20	0	82	365	162	56%	53%
84077	2.373	1.33772	2.2494	136	56	44	16	0	0	12	365	84	77%	56%
84078	2.476	1.38773	2.3466	140	53	63	15	0	0	12	365	80	78%	56%
84079	2.803	1.54435	2.6566	171	47	40	17	0	3	11	365	75	79%	55%
84081	2.26	1.26586	2.1423	126	52	44	22	0	5	6	365	80	78%	56%
84082	2.273	1.26053	2.154	127	72	49	39	0	0	2	365	113	69%	55%
84083	2.119	1.21252	2.0084	140	67	40	7	0	6	25	365	99	73%	57%
84084	2.515	1.3862	2.3841	153	62	28	13	0	0	22	365	97	73%	55%
84086	1.369	0.69977	1.2975	72	150	41	37	8	0	10	365	205	44%	51%
84087	2.413	1.34264	2.2873	158	51	29	11	6	11	22	365	90	75%	56%
84088	2.144	1.20217	2.032	139	39	29	28	8	0	18	365	93	75%	56%
84089	1.957	1.084	1.8553	125	61	28	9	0	0	56	365	126	65%	55%
84090	2.266	1.34945	2.1477	143	59	69	12	0	0	3	365	74	80%	60%
84092	2.506	1.4037	2.3753	153	72	31	14	2	0	2	365	90	75%	56%
84093	1.163	0.63243	1.102	73	41	23	13	89	0	73	365	216	41%	54%
84094	2.258	1.26432	2.1399	133	67	62	18	0	0	14	365	99	73%	56%
84095	1.405	0.80356	1.332	101	53	22	18	20	9	95	365	186	49%	57%

84096	2.644	1.509	2.506	162	36	38	14	0	0	11	365	61	83%	57%	77%
84097	2.488	1.688	2.358	117	53	50	18	4	6	11	365	86	76%	68%	57%
84098	2.353	2.222	2.23	149	65	50	8	0	0	23	365	96	74%	94%	66%
84099	2.471	1.357	2.342	155	43	48	22	0	10	4	365	69	81%	55%	69%
84100	1.454	0.731	1.378	99	38	35	27	0	0	108	365	173	53%	50%	65%
84101	2.287	1.272	2.168	137	53	40	20	23	0	0	365	96	74%	56%	71%
84102	2.166	1.201	2.053	142	46	51	15	0	0	34	365	95	74%	55%	64%
84103	2.309	1.285	2.188	150	64	39	17	0	9	8	365	89	76%	56%	74%
84104	2.347	1.373	2.224	141	59	31	18	0	0	3	365	80	78%	59%	78%
84105	2.564	1.441	2.43	149	43	34	23	0	5	4	365	70	81%	56%	77%
84106	1.84	1.091	1.744	124	43	46	52	0	0	32	365	127	65%	59%	63%
84107	2.001	1.081	1.897	136	72	40	23	11	13	6	365	112	69%	54%	71%
84108	1.982	1.112	1.879	131	35	28	27	0	7	51	365	113	69%	56%	79%
84109	2.604	1.446	2.468	152	41	41	20	0	3	18	364	79	-22%	56%	73%
84110	2.211	1.228	2.096	102	41	86	9	0	0	22	338	72	-2621%	56%	16%
84111	2.454	1.388	2.326	157	26	64	12	0	11	14	365	52	86%	57%	59%
84112	2.394	1.379	2.269	141	43	47	34	0	0	11	365	88	76%	58%	67%
84113	2.286	1.348	2.166	137	42	38	27	0	0	0	365	69	81%	59%	72%
84114	2.2	1.242	2.086	144	38	69	27	0	0	5	365	70	81%	56%	52%
84115	2.72	1.541	2.578	170	48	39	11	0	7	12	365	71	81%	57%	77%
84116	2.493	1.472	2.363	163	37	31	15	0	5	3	365	55	85%	59%	81%
84117	2.581	1.449	2.446	147	37	51	27	0	0	8	365	72	80%	56%	65%
84118	2.369	1.371	2.246	143	52	64	20	0	0	4	365	76	79%	58%	55%
84119	2.254	1.337	2.136	152	66	43	10	0	8	9	365	85	77%	59%	72%
84120	2.33	1.3	2.209	138	88	29	9	6	6	2	365	105	71%	56%	79%
84121	2.255	1.268	2.137	132	35	44	29	0	6	5	365	69	81%	56%	67%
84122	1.996	1.119	1.891	125	61	65	17	0	0	7	365	85	77%	56%	48%
84123	2.227	1.254	2.111	141	80	31	17	7	14	9	365	113	69%	56%	78%
84124	2.265	1.268	2.147	132	62	34	29	0	1	3	365	94	74%	56%	74%
84125	1.925	1.035	1.825	114	100	38	21	0	0	8	365	129	65%	54%	67%
84126	2.2	1.234	2.085	137	73	58	20	0	0	3	365	96	74%	56%	58%

84127	1.85	1.065	1.754	145	59	40	14	0	3	48	365	121	67%	58%	72%	28%
84129	2.171	1.21	2.058	126	72	42	12	11	0	12	365	107	71%	56%	67%	26%
84130	1.981	1.232	1.877	122	98	48	15	0	0	2	365	115	68%	62%	61%	26%
84131	2.092	1.143	1.983	142	59	33	24	0	14	12	365	95	74%	55%	77%	31%
84132	2.518	1.41	2.387	152	52	31	16	0	20	11	365	79	78%	56%	80%	35%
84133	2.429	1.362	2.302	150	21	59	22	0	4	13	365	56	85%	56%	61%	29%
84134	2.433	1.394	2.306	144	37	69	10	0	0	18	365	65	82%	57%	52%	25%
84135	0.52	0.354	0.493	42	9	15	3	178	0	5	275	195	-8971%	68%	64%	-3927%
84136	1.976	1.064	1.873	128	50	32	45	0	0	31	365	126	65%	54%	75%	26%
84137	2.163	1.219	2.05	136	50	39	32	0	6	0	365	82	78%	56%	71%	31%
84138	2.264	1.294	2.146	141	70	63	5	0	0	2	365	77	79%	57%	55%	25%
84139	2.874	1.579	2.724	183	31	43	20	0	5	9	365	60	84%	55%	77%	35%
84140	2.143	1.213	2.031	132	60	30	39	0	0	11	365	110	70%	57%	77%	31%
84141	2.159	1.241	2.046	128	65	38	31	4	10	4	365	104	72%	57%	70%	29%
84142	1.798	0.923	1.704	121	58	52	10	0	0	58	365	126	65%	51%	57%	19%
84143	1.685	0.925	1.597	137	32	34	7	0	11	95	365	134	63%	55%	75%	26%
84144	2.235	1.258	2.119	134	35	25	12	0	0	65	365	112	69%	56%	81%	32%
84145	2.926	1.617	2.773	164	39	35	10	0	0	0	365	49	87%	55%	79%	38%
84146	2.045	1.131	1.939	122	99	54	13	0	0	3	365	115	68%	55%	56%	21%
84147	2.344	1.296	2.222	162	53	33	16	0	14	8	365	77	79%	55%	80%	35%
84148	2.351	1.321	2.228	146	28	33	35	0	0	21	365	84	77%	56%	77%	33%
84149	2.378	1.277	2.254	137	47	51	19	0	0	12	365	78	79%	54%	63%	26%
84150	1.781	1.064	1.688	115	106	47	20	4	0	6	365	136	63%	60%	59%	22%
84152	2.007	1.073	1.902	128	57	32	37	0	5	12	365	106	71%	53%	75%	28%
84153	1.366	0.727	1.294	80	38	34	21	129	0	6	365	194	47%	53%	58%	14%
84154	1.402	0.832	1.329	85	171	35	17	0	0	4	365	192	47%	59%	59%	17%
84155	1.455	0.855	1.379	105	58	32	23	0	15	86	365	167	54%	59%	70%	22%
84156	2.19	1.205	2.075	126	83	32	8	9	4	8	365	108	70%	55%	75%	29%
84157	1.974	1.759	1.871	117	78	47	9	0	0	29	365	116	68%	89%	60%	36%
84158	2.429	1.384	2.302	156	45	70	9	0	0	7	365	61	83%	57%	55%	26%
84160	1.871	1.013	1.774	122	59	54	17	0	0	39	365	115	68%	54%	56%	21%

84161	2.273	1.263	2.1543	134	69	41	17	0	0	1	365	87	76%	56%	69%	29%
84162	2.373	1.341	2.2496	144	32	61	30	0	0	18	365	80	78%	57%	58%	25%
84163	1.561	0.856	1.4798	131	59	36	24	6	12	35	365	124	66%	55%	73%	26%
84164	2.079	1.182	1.97	125	99	39	12	0	0	3	365	114	69%	57%	69%	27%
84165	0.972	0.535	0.9214	101	28	25	17	0	0	141	365	186	49%	55%	75%	20%
84166	2.846	1.626	2.6971	158	37	78	13	0	0	1	365	51	86%	57%	51%	25%
84167	2.401	1.332	2.2755	164	38	34	21	3	13	22	365	84	77%	55%	79%	34%
84168	1.351	0.743	1.2805	81	80	19	10	125	0	1	365	216	41%	55%	77%	17%
84169	1.657	0.883	1.5708	121	53	35	28	0	5	30	366	111	170%	53%	71%	64%
84170	2.097	1.147	1.9874	129	80	54	21	0	0	3	365	104	72%	55%	58%	23%
84171	1.503	0.882	1.4245	121	82	27	19	0	6	56	365	157	57%	59%	78%	26%
84172	2.518	1.383	2.387	148	44	30	17	14	7	7	365	82	78%	55%	80%	34%
84173	2.472	1.275	2.3433	144	23	47	36	0	0	15	365	74	80%	52%	67%	28%
84174	2.402	1.352	2.2764	143	56	52	21	0	0	7	365	84	77%	56%	64%	28%
84175	2.223	1.322	2.1073	147	45	38	15	0	4	9	365	69	81%	59%	74%	36%
84176	2.154	1.126	2.0415	136	56	42	33	0	0	7	365	96	74%	52%	69%	27%
84177	1.5	1.261	1.4215	93	59	24	6	0	0	116	365	181	50%	84%	74%	31%
84178	0.964	0.537	0.9133	73	82	34	9	0	0	128	365	219	40%	56%	53%	12%
84179	0.895	0.491	0.8481	75	31	25	13	0	11	180	365	224	39%	55%	67%	14%
84180	2.258	1.349	2.1399	132	37	39	28	0	0	27	365	92	75%	60%	70%	31%
84181	2.32	1.285	2.1992	142	37	44	16	0	5	15	365	68	81%	55%	69%	31%
84182	1.942	1.129	1.8409	118	75	42	20	0	0	33	365	128	65%	58%	64%	24%
84183	2.718	1.909	2.5763	167	50	34	11	0	8	7	365	68	81%	70%	80%	46%
84184	1.998	1.111	1.8934	151	33	38	26	0	0	42	365	101	72%	56%	75%	30%
84186	2.072	1.131	1.964	139	47	56	30	0	0	8	365	85	77%	55%	60%	25%
84187	1.931	1.042	1.8305	135	56	69	15	0	3	14	365	85	77%	54%	49%	20%
84188	2.059	1.05	1.9512	135	57	20	40	0	0	19	365	116	68%	51%	85%	30%
84189	1.269	0.762	1.2028	116	31	27	17	0	9	78	365	126	65%	60%	77%	30%
84191	1.557	0.863	1.476	122	69	35	29	4	14	41	365	143	61%	55%	71%	24%
84192	2.337	1.242	2.2151	135	51	57	15	0	0	15	365	81	78%	53%	58%	24%
84193	2.426	1.367	2.2991	155	21	35	12	2	13	16	365	51	86%	56%	77%	38%
84194	2.141	1.132	2.029	139	68	70	12	0	0	6	365	86	76%	53%	50%	20%

84195	2.499	1.3631	2.3688	160	52	31	12	0	6	8	365	72	80%	55%	81%
84197	1.964	1.0563	1.8612	122	56	42	24	10	3	21	365	111	70%	54%	66%
84198	2.093	1.1585	1.9839	133	69	43	5	0	0	43	365	117	68%	55%	68%
84199	2.444	1.4057	2.3163	155	52	51	15	0	10	3	365	70	81%	58%	67%
84201	2.283	1.2032	2.1642	128	33	39	30	0	6	33	365	96	74%	53%	70%
84202	1.944	1.112	1.8421	127	43	71	8	0	0	26	365	77	79%	57%	44%
84203	2.233	1.2441	2.1167	144	50	56	33	0	8	5	365	88	76%	56%	61%
84204	2.532	1.3482	2.4001	153	22	31	27	0	3	22	365	71	81%	53%	80%
84205	2.525	1.3129	2.3927	142	51	44	19	0	3	11	365	81	78%	52%	69%
84206	2.506	1.4369	2.3755	140	66	55	17	0	0	4	365	87	76%	57%	61%
84207	2.358	1.3792	2.235	157	30	45	13	0	16	9	365	52	86%	58%	71%
84208	2.375	1.3621	2.2507	144	65	34	16	0	7	4	365	85	77%	57%	76%
84209	1.439	0.7179	1.3642	102	73	28	9	0	1	65	365	147	60%	50%	73%
84210	2.158	1.166	2.0451	135	53	59	15	0	0	28	365	96	74%	54%	56%
84211	2.92	1.6071	2.768	184	40	42	7	0	3	3	365	50	86%	55%	77%
84212	2.406	1.3425	2.2801	147	58	35	21	1	0	9	365	89	76%	56%	76%
84213	2.337	1.272	2.2151	134	42	49	18	0	2	25	365	85	77%	54%	63%
84214	2.04	1.1534	1.9339	119	73	65	24	0	0	4	365	101	72%	57%	45%
84215	2.414	1.3652	2.2876	172	39	45	8	0	13	10	365	57	84%	57%	74%

Appendix C Codes for CMMS

```
// To Show Data
1 reference
private void Showdata()
{
    try
    {
        SqlConnection con = new SqlConnection(Conn.Db);
        con.Open();
        string str = ("SELECT * FROM TruckTbl");
        SqlCommand cmd = new SqlCommand(str, con);

        cmd.ExecuteNonQuery();

        DataTable dt = new DataTable();

        SqlDataAdapter da = new SqlDataAdapter(cmd);

        da.Fill(dt);

        //method 1-direct method
        TDGV.DataSource = dt;
        con.Close();

    }
    catch (Exception ex)
    {
        MessageBox.Show(ex.Message);
    }
```

```
try
{
    if (txt_employeename.Text == "")
    {
        MessageBox.Show("Please Enter Employee Name", "Try again", MessageBoxButtons.OK, MessageBoxIcon.Information);
        txt_employeename.Focus();
    }
    else if (txt_employeeID.Text == "")
    {
        MessageBox.Show("Please Enter Employee ID", "Try again", MessageBoxButtons.OK, MessageBoxIcon.Information);
        txt_employeeID.Focus();
    }
    else if (txt_employeeadress.Text == "")
    {
        MessageBox.Show("Please Enter Employee Adress", "Try again", MessageBoxButtons.OK, MessageBoxIcon.Information);
        txt_employeeadress.Focus();

    }
    else if (txt_Gender.Text == "")
    {
        MessageBox.Show("Please Enter Employee Gender", "Try again", MessageBoxButtons.OK, MessageBoxIcon.Information);
        txt_Gender.Focus();
    }
    else
    {
        SqlConnection con = new SqlConnection(Conn.Db);

        con.Open();

        string str = "Insert Into EmployeeTbl(employeename,employeeID,employeeadress,Gender) Values ('" + txt_employeename.Text + "
        SqlCommand cmd = new SqlCommand(str, con);
```

```
private void CountTrucks()
{
    SqlDataAdapter sda = new SqlDataAdapter("select count(*) from TruckTbl",Con);
    DataTable dt = new DataTable();
    sda.Fill(dt);
    lbl_totaltrucks.Text = dt.Rows[0][0].ToString();
}
2 references
private void SumAmount()
{
    SqlDataAdapter sda = new SqlDataAdapter("select Sum (TotalCost) from CostTbl", Con);
    DataTable dt = new DataTable();
    sda.Fill(dt);
    lbl_totalcost.Text = dt.Rows[0][0].ToString();
}
2 references
private void CountEmployee()
{
    SqlDataAdapter sda = new SqlDataAdapter("select count(*) from EmployeeTbl", Con);
    DataTable dt = new DataTable();
    sda.Fill(dt);
    lbl_totalemployee.Text = dt.Rows[0][0].ToString();
}
2 references
private void CountSpare()
{
    SqlDataAdapter sda = new SqlDataAdapter("select count(*) from StoreTbl", Con);
    DataTable dt = new DataTable();
    sda.Fill(dt);
    lbl_totalspare.Text = dt.Rows[0][0].ToString();
}
1 reference
```

```
{
    if (txt_sparepartcost.Text == "")
    {
        MessageBox.Show("Please Enter Spare Part Cost", "Try again", MessageBoxButtons.OK, MessageBoxIcon.Information);
        txt_sparepartcost.Focus();
    }
    else if (txt_employeecost.Text == "")
    {
        MessageBox.Show("Please Enter Employee Cost", "Try again", MessageBoxButtons.OK, MessageBoxIcon.Information);
        txt_employeecost.Focus();
    }
    else if (txt_othercost.Text == "")
    {
        MessageBox.Show("Please Enter Other Cost", "Try again", MessageBoxButtons.OK, MessageBoxIcon.Information);
        txt_othercost.Focus();

    }
    else if (txt_totalcost.Text == "")
    {
        MessageBox.Show("Please Enter Total Cost", "Try again", MessageBoxButtons.OK, MessageBoxIcon.Information);
        txt_totalcost.Focus();
    }
    else
    {
        SqlConnection con = new SqlConnection(Conn.Db);

        con.Open();

        string str = "Insert Into CostTbl(sparepartcost,employeecost,othercost,totalcost) Values ('" + txt_sparepartcost.Text + "',
        SqlCommand cmd = new SqlCommand(str, con);

        cmd.ExecuteNonQuery();

        string str1 = "Select max(totalcost)From CostTbl";
```

```
public User_Report()
{
    InitializeComponent();
}

1 reference
private void BtnReport_Click(object sender, EventArgs e)
{
    try
    {
        using(CMMSDbEntities2 db = new CMMSDbEntities2())
        {
            truckTblBindingSource.DataSource = db.TruckTbls.ToList();
            employeeTblBindingSource.DataSource = db.EmployeeTbls.ToList();
            storeTblBindingSource.DataSource = db.EmployeeTbls.ToList();
            costTblBindingSource.DataSource = db.CostTbls.ToList();
            reportViewer1.RefreshReport();
        }
    }
    catch(Exception ex)
    {
        MessageBox.Show(ex.Message, "message", MessageBoxButtons.OK, MessageBoxIcon.Information);
    }
    this.reportViewer1.RefreshReport();
}

1 reference
private void reportViewer1_Load(object sender, EventArgs e)
{
    this.reportViewer1.RefreshReport();
}
```

```
    {
        SqlConnection con = new SqlConnection(conn.Db);

        con.Open();

        string str = "Update StoreTbl Set sparepartname ='" + txt_sparepartname.Text + "',sparepartnumber ='" + txt_sparepartnumber
        SqlCommand cmd = new SqlCommand(str, con);

        cmd.ExecuteNonQuery();

        string str1 = "Select max(sparepartquantity)From StoreTbl";

        SqlCommand cmd2 = new SqlCommand(str1, con);

        SqlDataReader da = cmd2.ExecuteReader();
        if (da.Read())
        {
            MessageBox.Show("Completed", "Thank you!!", MessageBoxButtons.OK, MessageBoxIcon.Information);
            Clear();
            Showdata();
        }
        else
        {
            MessageBox.Show("Error", "please Use The Right Information!!", MessageBoxButtons.OK, MessageBoxIcon.Information);
        }
    }
}
catch (Exception ex)
{
    MessageBox.Show(ex.Message);
}
```

x

የኢትዮጵያ የባሕር ትራንስፖርትና ሎጅስቲክስ
አገልግሎት ድርጅት ቃሊቲ ቅርንጫፍ
ETHIOPIAN SHIPPING & LOGISTICS
SERVICES ENTERPRISE KALITY BRANCH

ቀን/Date 20/04/2015
ቁጥር/Our Ref 02/1737/13

ለአዳማ ሳይንስና ቴክኖሎጂ ዩንቨርስቲ
አዳማ፣

ጉዳዩ፡- ትብብርን ይመለከታል፣

ታህሳስ 18 ቀን 2015 ዓ/ም በቁጥር MEng/1345/12/2022 ከመካኒካል ምህንድስና የትምህርት ክፍል በተላፈ ደብዳቤ የድርጅታችን ሠራተኛ የሆኑት አቶ ከበበ ኡርጌ በተቋማችሁ በመካኒካል ምህንድስና የሁለተኛ ዲግሪ መሆናቸው በመጥቀስ የመመረቂያ ፅሁፋቸውን በመስራት ላይ በመሆናቸው ለጥናቱ የሚያስፈልጋቸውን መረጃ ትብብር እንዲደረግላቸው የተጠየቁ መሆኑ ይታወሳል።

በመሆኑም ተጠቃሽ እየሠሩበት ባለው የተሽከርካሪ ቴክኒክ መምሪያ አስተያየት እንዲሰጥበት ተጠይቆ የመመረቂያ ፅሁፋቸውን የሚያግዝ መረጃ ሲጠየቁ ትብብር እንደሚደረግላቸው የተገለፀልን መሆኑን እናስታውቃለን።

ከሠላምታ ጋር

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