



Improvement of Maintenance Management System (MMS) for Increasing Energy Efficiency The Case Study of Brewery Industries in Tanzania

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Abstract: Buildings and machinery in brewery industries in Tanzania work effectively and efficiently when the conflicts between energy performance and maintenance are balanced, and in order to attain optimal energy performance, proper maintenance is required. Although many of the brewery industries in Tanzania have implemented and adopted preventive maintenance practices, there has been a rise in utility costs because of excessive energy consumption, particularly in gas (m³) and electricity (KWh), which is directly tied to maintenance practices. This study was conducted with the intention of identifying the factors affecting the maintenance management system, which will improve energy efficiency at breweries in Tanzania. The study adopted a qualitative approach for data collection and a quantitative approach for quantifying the problem. The literature review, fishbone diagram, questionnaires, field measurements, inspections, and observations were all part of the research methodology. Through a questionnaire submitted to 40 respondents, 38 questionnaires received and analyzed. Analysis employed to determine and identify factors (variables) that contribute to the dependent variable as well as decide which ones to keep in consideration of their contributions, and these carried out using the IBM SPSS Statistics Version 26 package. Factors with the highest RII were termed as significant factors affecting the maintenance management system that improves energy efficiency at Brewery Industries in Tanzania. Lack of energy expertise and skills, condition monitoring technologies, lack of energy audits, and skipping of maintenance were termed as significant factors, having Relative Importance Index (RII) of 0.84, 0.81, 0.77, and 0.75 respectively. If those factors are eliminated, maintenance management and energy efficiency in breweries is improved. The identified factors were used to develop Maintenance Management Model for brewery Industries in Tanzania, where multiple regression and stepwise method were used to develop the model. Maintenance factors affecting energy efficiency improved by increasing energy expertise, implementing condition monitoring technologies, reducing skipping of maintenance, and performing energy audits by 0.219, 0.257, -0.114, and 0.201, respectively. According to the findings, it is recommended that industries ensure that employees have adequate training in energy management techniques, advance monitoring technology, have a plan in place for conducting energy audits at least twice a year, and ensure that preventative maintenance is not neglected.

Key words: Maintenance Management system, Energy Efficiency, Brewery Industries in Tanzania

1.0 INTRODUCTION

Alcohol and beer are significant elements of Tanzanian culture, and Tanzanians take great pleasure in their home brands. With nearly 3% of the continent's consumption, Tanzania ranks sixth in Africa for beer consumption. Most of brewery industries across the globe are currently struggling with high-energy usage based on electricity, gas, diesel, and fuel oil as a source of energy, which is directly tied up with maintenance activities, which an ends it drives up budget expenses and increase in operating costs.

Energy efficiency refers to utilization of energy in the best possible way to perform a task that could have been completed using a more conventional, using less energy while yet producing the necessary amount of energy (Corrosionpedia, 2020). In other hand Maintenance is the combination of all technical, administrative, and managerial steps taken over the course of a product's lifecycle with the goal of keeping it in or regaining it to a state where it can carry out its intended function (Choudhary, 2016).

Equipment and machinery in Brewery Industries across Tanzania and worldwide work effectively and efficiently when the conflicts between energy performance and maintenance are balanced, energy inefficiency would be the results of a significant association between three components, including an effective preventive maintenance programme and other aspects like spare parts availability and maintenance staff skills (Al-Ghanim, 2003).

Figure I shows electricity energy distribution across the brewery plants and Figure II show how steam energy distributed across Brewing and Packaging section, which is used as source of heat.

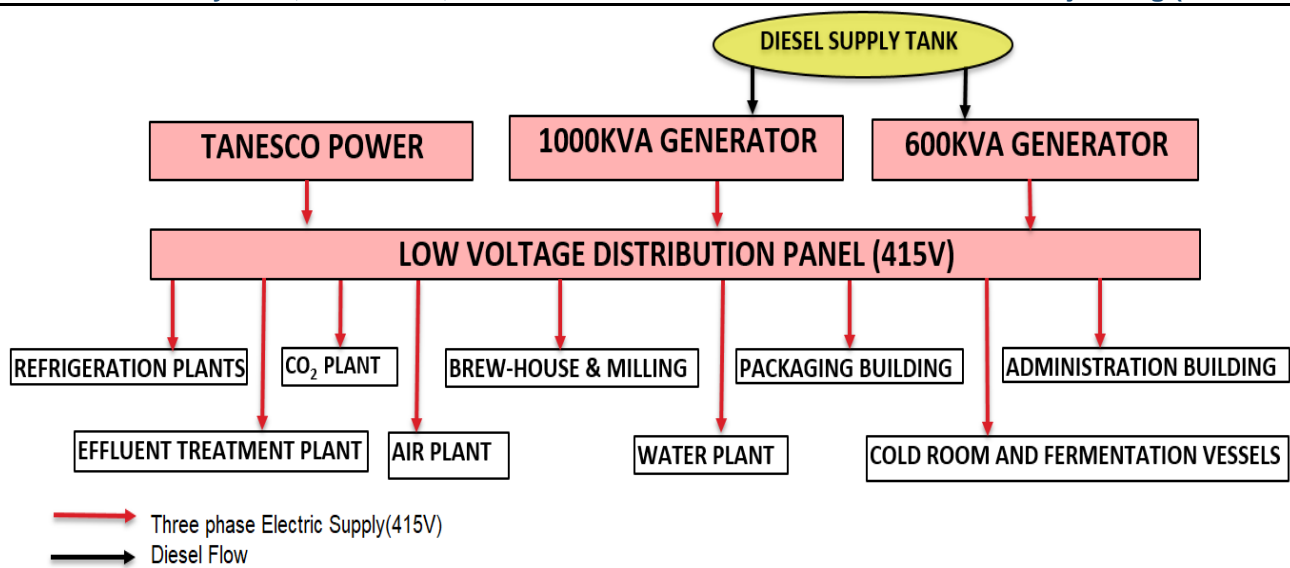


Figure I: Electricity energy distribution at Brewery Industries in Tanzania (Diageosharepoint, 2020)

Steam simple flow diagram

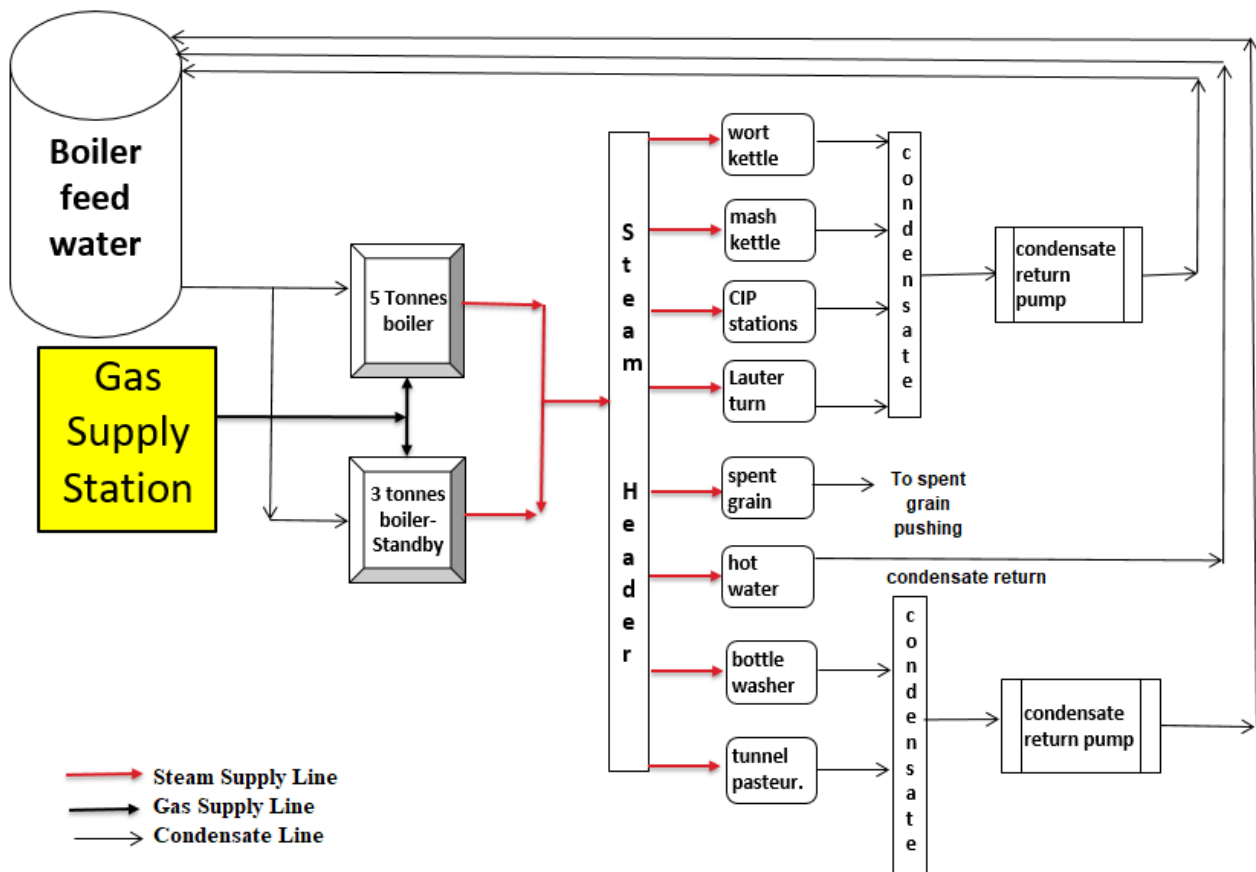


Figure II: Steam energy distribution (Diageosharepoint, 2020)

Plambeck, (2012) explained how programs that promote energy efficiency are crucial for lowering energy costs and consumption. By implementing energy efficiency technologies energy efficiency will be improved. Operational or production improvements might help reduce energy use.

Dynamic business, increase in maintenance costs and utilities costs. These factors drive most of the brewery companies in Tanzania to implement and adopt preventive maintenance. However, despite this adoption, most of the brewery companies still experience an increase in utilities costs, which caused by high-energy consumption both in electricity (kWh) and in gas (m³), which is directly related to maintenance practices. Lewis et al., (2012) explain that, In order to attain optimal energy performance, proper maintenance is required, and efficient maintenance management requires data on energy performance.

The main objective of the paper is to improve Maintenance Management System (MMS) for increasing energy efficiency at Brewery Industries in Tanzania. In order to achieve the main goals, we must first identify the factors (variables) that affect the Maintenance Management System (MMS) for improving energy efficiency at Brewery Industries in Tanzania, then develop a Maintenance Management Model, and lastly to develop the Maintenance Management System for improving energy efficiency at Brewery Industries in Tanzania. These will be achieved using IBM SPSS Statistics package which will help analyze the factors (variables) influencing the maintenance management system and design a maintenance management model for increasing energy efficiency at brewery industries in Tanzania.

1.1 Total electricity energy usage versus the plan

According to published research, reveals that the amount of energy supplied in the industrial sector approximately 25 % to 30% of the total energy is used. Industry energy management is crucial from a firm and a national standpoint (Hunt Allcott, 2013). Figure III. Show current energy consumption of one of the brewery company in Tanzania which was taken daily through meter readings based on Gas in meter cubic (m³) and electricity in Kilo watt hours (Kwh), From the graph, Energy consumption based on both gas and electricity is not achieved for the two consecutive years both (2020/2021) and (2021/2022).

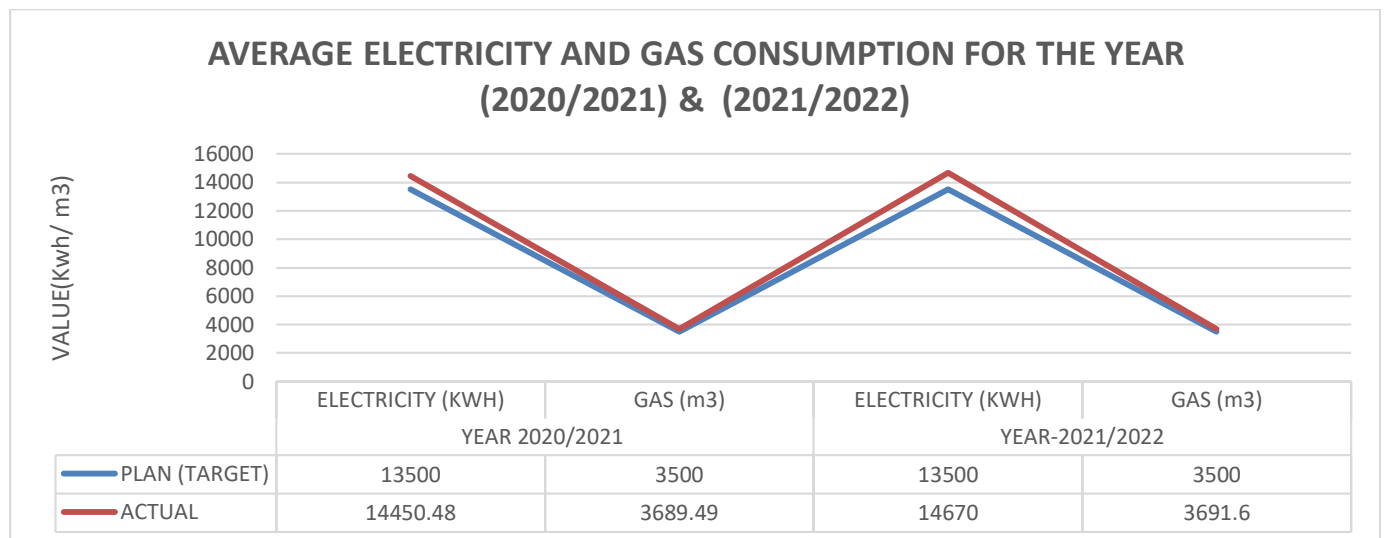


Figure III: Electricity and gas consumption for year (2020/2021) & (2021/2022) (Diageosharepoint, 2020)

2.0 FACTORS AFFECTING MAINTENANCE MANAGEMENT SYSTEM FOR IMPROVING ENERGY EFFICIENCY AT BREWERY INDUSTRIES IN TANZANIA

Finding maintenance management aspects that have an impact on energy efficiency is essential for Brewery industries in Tanzania in order to reduce consumption and conserve energy. Table I, shows the list of numerous maintenance factors that have an impact on energy efficiency, which obtained from different literature review and where grouped into several aspects.

Table I: Summary on the Factors Affecting Maintenance Management System for Improving Energy Efficiency at Brewery Industries

| Factor Affecting Maintenance Management at Brewery Industries | Author's name and Year |
|---|---|
| Factor related to equipment and machines | (Santolamazza, Cesarotti, & Introna, 2018) |
| Aging resources | (Farber, 2021) |
| Mechanical failure of equipment | (Abouelanouar, Elkihel, & Gziri, 2020) |
| Bad design of technical resources | (Seow, Goffin, Rahimifard, & Woolley, 2016) |
| Factors related to energy management | (Lewis et al., 2012) |
| Lack of power and influence by those in charge of energy management | (Gupta R. & M, 2015) |
| Lack of energy audits | (U.S. Dept. Of Energy, 2017) |
| Condition monitoring technology | (Knowles & Baglee, 2012), (Trust, 2012) |
| Lack of energy expert and skills | (Act, 2001) |
| Factors related to spare parts | (Kui Chen & Jiao, 2021) |
| Spare parts availabilities | (Kui Chen & Jiao, 2021) |
| Quality of the spare parts | (Yamato, 2018) |
| Dimensional Accuracy of spare parts | (Aissa Ouballoucha et al., 2019) |
| Factor related to human Resources | (Emex, 2022) |
| Lack of technical skills | (Apeaning & Thollander, 2013) |
| Human behavior | (Andrews Rn & E, 2016) |
| Human and operation errors | (Hong, D'oca, Turner, & Taylor-Lange, 2015) |
| Factors related to maintenance management practices | (Andre, 2021; Behnoush Darabnia, 2013) |
| Housekeeping and maintenance in industrial facilities | (Gordić D, 2010), (O'rielly & Jeswiet, 2014). |
| Lack of time for maintenance | (Cousineau, 2018) |
| Planning and scheduling | (Hippocmms, 2021) |
| Resource planning | (Saviom, 2022) |
| Skipping of maintenance | (Gilbert, 2021) |
| Maintenance policy and strategy | (Limble, 2021) |
| Maintenance management system control | (Haroun, 2015) |

3.0 MATERIAL AND METHODS

The literature review, fishbone diagram, questionnaire, inspections, and observations were all part of the research methodology. The questionnaire designed to identify the maintenance management aspects that have an impact on energy efficiency at brewery industries in Tanzania. Both maintenance professionals and end users were taken into consideration when designing the questionnaire. Among

questionnaire that submitted to 40 respondents, 38 respondents filled and returned the questionnaire. The demographic information of the respondents was examined using descriptive statistics, and their ratings of the factors influencing maintenance management examined using mean score ranking (MSR) and the Relative Importance Index (RII) (Kassem, 2020).

$$\text{Relative Important Index (RII)} = \frac{\sum W}{A \times N} \quad (0 \leq \text{RII} \leq 1) \quad (1)$$

Where,

W= Weight given to each factor by the respondents ranging from 1 to 5

A = the highest weight and N is the total number of respondents, Based on the value of their relative importance index (RII), as indicated in Table II, all components are rated according to their level or degree of Significance.

Table II: Degree of Significance (Kassem, 2020)

| No. | Degree of Significance | Rating |
|-----|------------------------|----------------|
| 1 | Most significant | 0.76 and Above |
| 2 | Significant | 0.67-0.75 |
| 3 | Less significant | 0.45-0.67 |
| 4 | Not Significant | 0.44 and below |

4.0 DATA COLLECTION AND ANALYSIS

Data collection involved multiple collection methods and techniques including conducting questionnaire, visual inspection and observation, reviews of documents for both machines and historical energy data which was collected on daily basis. Forty (40) respondents received the questionnaire and thirty-eight (38) returned which is approximately to 95%. The group targeted involved Technical operators, Maintenance technicians, maintenance engineers, maintenance planners, packaging Team leaders, Shift brewers and Engineering managers.

The questions were prepared in the form of five (5) point Likert scale which were scaled as; 5 =strongly agree, 4=Agree, 3= No option, 2=Disagree, 1=Strong disagree. Through the qualitative approach, the researcher measured the extent of the factors affecting maintenance management system for improving energy efficiency and Relative Important Index (RII) ranking used to rank factors that affecting maintenance management system for improving energy efficiency. The analysis shows that, lack of energy expertise and skills, condition monitoring technologies, a lack of energy audits, skipping of maintenance, a lack of technical skills, human behavior, mechanical failure of equipment, human and operation errors, housekeeping and maintenance, and maintenance control having a Relative Importance Index (RII) of 0.84, 0.81, 0.77, 0.75, 0.74, 0.74, 0.72, 0.71, 0.67, and 0.67 respectively, are the factors affecting the maintenance management system for improving energy efficiency at brewery industries in Tanzania.

Table III. Factors affecting maintenance management system for improving energy efficiency and their mean scores

| S/N | Factors affecting maintenance management system for improving energy efficiency | Mean scores | S/N | Factors affecting maintenance management system for improving energy efficiency | Mean scores |
|-----|---|-------------|-----|---|-------------|
| 1 | Aging resources | 2.45 | 7 | Lack of technical skills | 3.42 |
| 2 | Mechanical failure | 3.37 | 8 | Human behavior | 3.45 |
| 3 | Bad design of technical resources | 1.97 | 9 | Human operational errors | 3.16 |
| 4 | Lack of power and influence by those in charge of energy management | 1.92 | 10 | Housekeeping and maintenance in industrial facilities | 2.79 |
| 5 | Lack of energy audits | 3.66 | 11 | Lack of time for maintenance | 1.61 |
| 6 | Condition monitoring technologies | 3.92 | 12 | Planning and scheduling | 2.66 |
| 7 | Lack of energy expertise and skills | 4.13 | 18 | Resource planning | 1.63 |
| 8 | Lack of budget funding | 2.26 | 19 | Skipping of maintenance | 3.47 |
| 9 | Availability of spare parts | 1.74 | 20 | Maintenance policy and strategy | 2.63 |
| 10 | Quality of spare parts | 2.37 | 21 | Maintenance management system controls | 2.76 |
| 11 | Dimensional accuracy of spare parts | 2.74 | | | |

4.1 Evaluation of Existing Measures on the Factors Affecting Maintenance Management System

The existing actions being taken or used at the brewery industries in Tanzania were considered increase energy efficiency. In order to determine how well the measures are being implemented and what needs to be improved, respondents were instructed to rate them on a scale of 0%, 25%, 50%, 75%, or 100%. The present measures on the maintenance management factors affecting energy efficiency were ranked using a mean score system. The measures that were selected had low mean values and, if put into practice, would increase energy efficiency.

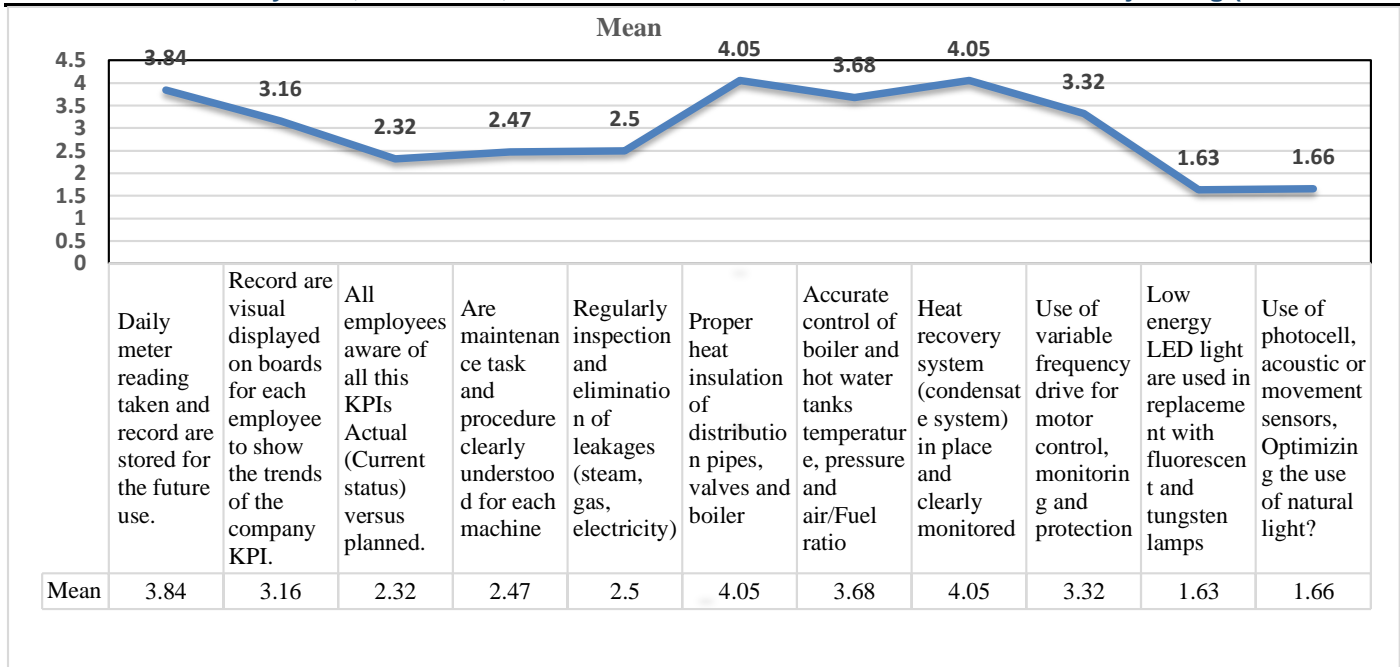


Figure IV: Evaluating measures on the maintenance management factors affecting energy efficiency at Brewery Industries in Tanzania

4.2 Other Maintenance Related Factors Affecting Energy efficiency at Breweries Industry in Tanzania

In order to reduce gas consumption, it is necessary to reduce steam waste points or leaks. Several steam leaks were observed from steam valves, steam pipe connections, and fittings. Leaks from pipes and malfunctioning valves must be repaired and stopped. When considering condition based monitoring of any machine, several devices like gauges are used to monitor the condition of either flow, pressure, or temperature. To know if the machine operates on its normal operating condition the gauges were used to track, and in case of any range below and above the limits can be easily captured and the issue can be early addressed.



Plate 1: Steam leakage at pasteurizer at packaging and Damaged Pressure gauge with no Pointer ((EABL), 2020)

5.0 DEVELOPMENT OF MAINTENANCE MANAGEMENT MODEL

Development of model on the maintenance management factors affecting energy efficiency involves two variables, dependent and independent variables. Multiple regression model used in this research to analyze the factors. Pearson correlation was used to measure the strength between two variables, and the effects of R-square (adjusted), standard error, and Durbin Watson of control block and treatment block were used to statistically check for consistency and validity.

$$EE_{(T)} = \beta_0 + \beta_1 X_{(EE)} + \beta_2 X_{(EA)} + \beta_3 X_{(CM)} + \beta_4 X_{(SM)} \tag{2}$$

Where,

EE (T) = Dependent variable (Energy Efficiency) and independent variables are:

X (EE) = Lack of energy expertise and skills,

X (EA) = Lack of energy Audits

X (CM) = Condition monitoring Technologies,

X (SM) = Skipping of Maintenance,

β₀ = Constant value, and β₁, β₂, β₃, β₄, and β₅ are coefficients of the predictor variables,

Thus, substituting coefficients values to the equation gives

$$EE_{(T)} = 1.840 + 0.210X_{(EE)} + 0.201X_{(EA)} + 0.296X_{(CM)} - 0.144X_{(SM)} \tag{3}$$

These demonstrate that increasing energy expertise, implementing condition monitoring technologies, reducing maintenance skipping, and performing energy audits by 0.219, 0.257, -0.114, and 0.201, respectively, will improve the maintenance management system and thereby increase energy efficiency at Brewery Industries in Tanzania.

5.1 Model Validation

Model validation is the process by which model outputs are (systematically) compared to independent real-world observations to judge the quantitative and qualitative correspondence with reality (P.M. Eldridge & Roelke, 2011). For effective model, validation is needed and therefore the calculated results in the mathematical model and simulated results are compared to validate the model calculated results. The results from SPSS software were obtained as shown on the table IV

Table IV: Model Validity Test

| S/N | Factor Effect | Control Block | Treatment Block |
|-----|--|--|---|
| 1 | Maintenance management Model for improving energy efficiency at Breweries Industries In Tanzania | $EE_{(T)} = 1.830 + 0.190X_{(EE)} + 0.198X_{(EA)} + 0.289X_{(CM)} - 0.143X_{(SM)}$ Durbin Watson = 2.178 R-square. = 0.91 R-square. (adjusted) = 0.71 | $EE_{(T)} = 1.740 + 0.170X_{(EE)} + 0.161X_{(EA)} + 0.255X_{(CM)} - 0.125X_{(SM)}$ Durbin Watson = 1.67 R-square. = 0.65 R-square. (adjusted) = 0.55 |

6.0 DEVELOPMENT OF MAINTENANCE MANAGEMENT SYSTEM

6.1 Conceptual Framework

A Conceptual Framework becomes an analytical tool as a result, it is employed to assemble many thoughts and draw conceptual differences. Strong conceptual frameworks enable the achievement of the targeted goal (Sommerville, 1989).

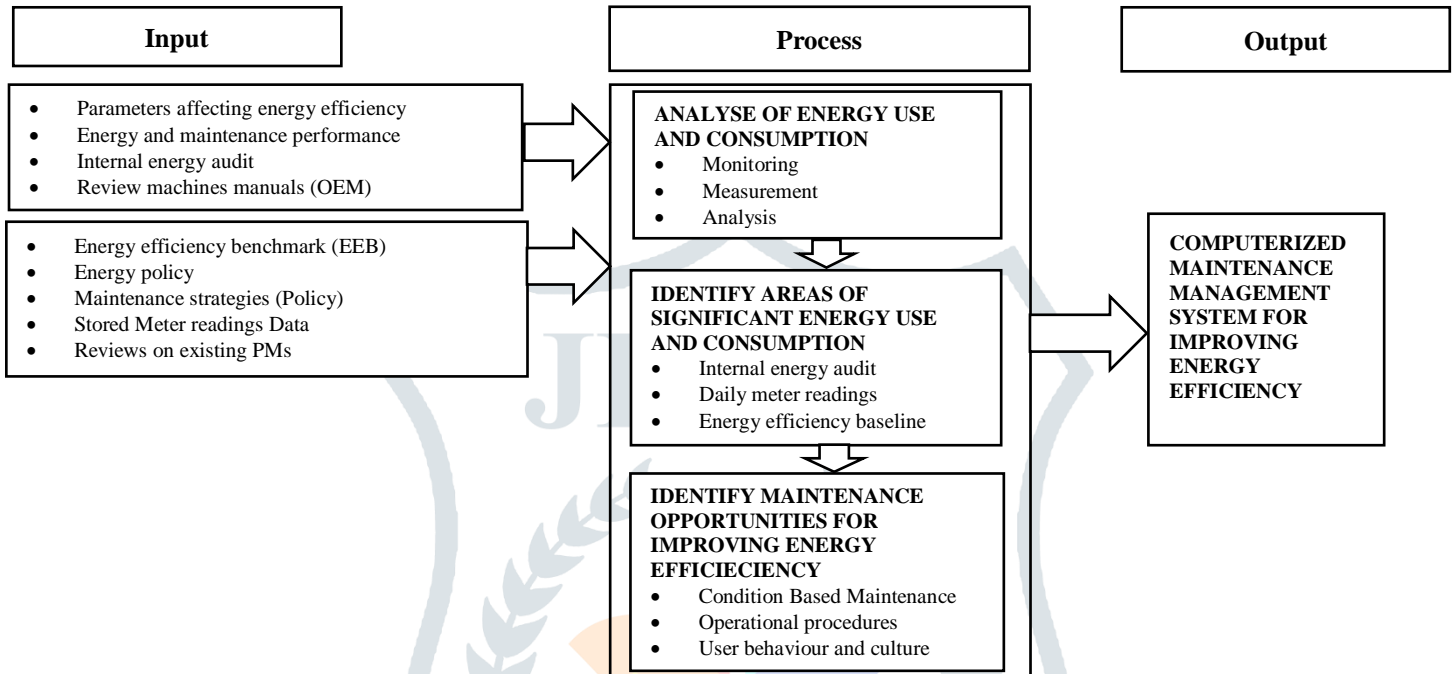


Figure V: Conceptual Framework

6.2 The Developed Maintenance Management System

The developed maintenance management system allows user to insert and store condition-monitoring data which will be used to detect performance changes. It also helps to decide for asset maintenance before it breaks down or deteriorate that affects output. Development of maintenance energy related tasks also help to improve all machines energy related issue. The developed maintenance management system further allows user during the operation to save/store energy data and operation manuals documents for a particular machine.

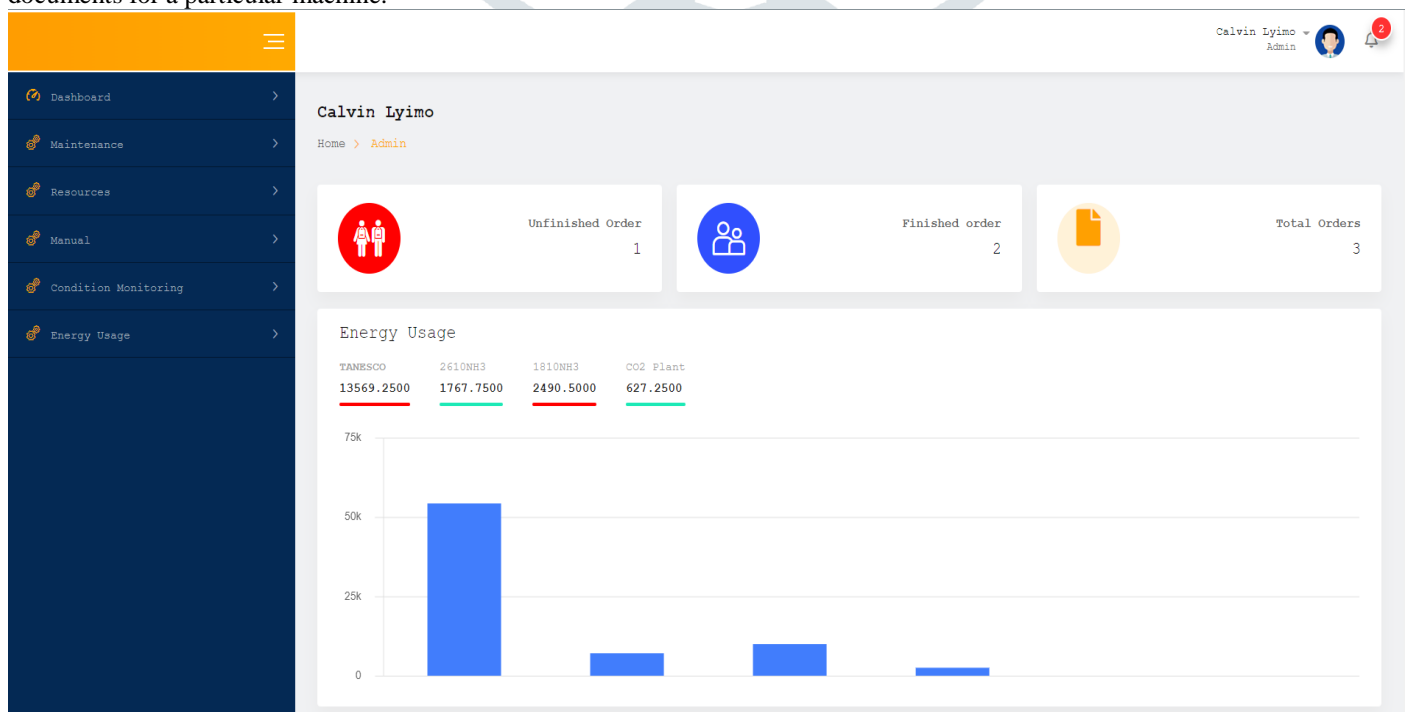


Figure VI: Maintenance Management System Developed

7.0 RESULTS

The first objective of this research is to identify factors affecting maintenance management systems for improving energy efficiency at brewery industries in Tanzania, and the identification of these factors was grouped into five (5) factors, which are: factors related to equipment and machines; factors related to energy management; factors related to spare parts; factors related to human resources; and factors related to maintenance. All the mentioned factors were subdivided into sub factors, which were part of the questionnaire and discussed below.

7.1 Evaluating the Factors Affecting Maintenance Management System for Improving Energy efficiency at Brewery Industries in Tanzania

Through literature review, the study identified and assessed the maintenance management factors that can improve the energy efficiency at brewery industries in Tanzania. These factors then ranked according to RII by respondent ratings, as shown on Table IV

Table V: Ranking the factors affecting maintenance management system for improving energy efficiency at Brewery Industries in Tanzania

| S/N | Factors | Rank | RII | Significance Level |
|-----|---|------|------|--------------------|
| 1 | Lack of energy expertise and skills | 1 | 0.84 | Most Significant |
| 2 | Condition monitoring technologies | 2 | 0.81 | Most Significant |
| 3 | Lack of energy audits | 3 | 0.77 | Most Significant |
| 4 | Skipping of maintenance | 4 | 0.75 | Significant |
| 5 | Lack of technical skills (Knowledge) | 5 | 0.74 | Significant |
| 6 | Human Behaviors | 6 | 0.74 | Significant |
| 7 | Mechanical failure of Equipment. ie Misalignments | 7 | 0.72 | Significant |
| 8 | Human and Operational Errors | 8 | 0.71 | Significant |
| 9 | Housekeeping and maintenance in industrial facilities | 9 | 0.67 | Significant |
| 10 | Maintenance management system controls | 10 | 0.67 | Significant |
| 11 | Aging Resources | 11 | 0.66 | Less Significant |
| 12 | Planning and scheduling | 12 | 0.66 | Less Significant |
| 13 | Quality of spare parts | 13 | 0.65 | Less Significant |

8.0 DISCUSSIONS

This part discuss the findings from the study and covers the discussion on the factors with significance value as highlighted in Table III. The variable affects the maintenance management system for energy efficiency, and the variable used to develop a model and develop a maintenance management system for improving energy efficiency at brewery industries in Tanzania.

8.1 Factors Affecting Maintenance Management System for improving Energy Efficiency at Brewery industries in Tanzania

Personnel with knowledge and experience in energy management skills are mostly lacking in brewery industries in Tanzania, having such personnel with all required skills and experience in solving energy issue will help improve staff awareness and assist in identifying and resolving any energy concerns. Operators must also be familiar with and comprehend all operating protocols, including when to turn machines on and off in response to user demand in the plant. Further, using condition monitoring technologies, it is possible to plan maintenance or take other steps to minimize or address the maintenance factors affecting energy efficiency before they develop into a major failure. One special advantage of continuous condition monitoring is that it helps to eliminate and be aware of all energy related issues. It allows for early intervention of disorders that might otherwise limit a normal lifetime. It also advised to conduct energy audit; the energy audit provides a thorough evaluation of the energy usage and power. An energy audit should include a technical report and suggestions for how to increase energy efficiency. Audit should involve experts who are aware of all potential options for energy savings and who are capable of conducting the audit and offering consulting services to resolve the problem. There is also a concern that company skip maintenance due to the increased market demand for its products. An energy-efficient machine is one that well maintained and operates at peak performance. Therefore, it is advised that the company implement a proactive maintenance program to direct the work of the maintenance department. The best practices for Preventive Maintenance program involves routine asset inspections with the goal of identifying energy related issues and resolving them before the asset degrades to the point that it can no longer function effectively and hence become energy inefficient.

8.2 Other Maintenance Related Factors Affecting Energy Efficiency at Brewery industries in Tanzania

The effectiveness of maintenance tasks and measuring or evaluating the effectiveness of completed jobs are the sub-maintenance factors related to the maintenance management system and control affecting energy efficiency at brewery industries in Tanzania. To conserve energy and lower consumption in brewery industries in Tanzania, it is crucial to analyze the elements that affect brewery energy usage section by section. A lack of condition monitoring tools to monitor leakages in the steam and sterile airlines, a malfunctioning steam condensate pump, a lack of machine controls and maintenance, the use of machines and devices with high power ratings, and power cable loss are the sub-maintenance factors that contribute to energy inefficiency. In a condition monitoring system, a machine's parameters should be either continuously watched or checked on a regular basis to identify any noticeable changes, which are typically signs of a breakdown in progress. The impact of these factors increases the amount of electricity and natural gas consumed, resulting in higher utility and maintenance costs. In order to improve energy efficiency, packaging and utility assets should be well maintained, and the company should make sure that people rely more on proactive than reactive maintenance.

9.0 CONCLUSION AND RECOMMENDATIONS

9.1 Conclusion

In order to establish sustainable and best maintenance practices that are compatible with lowering utilities and maintenance costs, some maintenance factors affecting energy efficiency in the brewery industry in Tanzania have been examined in this paper and recommendations have been made to improve them. The research also emphasizes the severity of the brewing industry's maintenance deficiencies, which require immediate repair.

The study implies that the current maintenance management system for improving energy efficiency at brewery industries in Tanzania has been affected by lack of energy expertise and skills, condition monitoring technologies, energy audit and skipping maintenance, if those factors are eliminated energy efficiency in brewery industries in Tanzania will improve.

Managing energy efficiency is crucial from a firm and a national standpoint. There are potential benefits for the company to manage energy for a business, such as not spending more on energy than necessary and maintaining the most cost-effective energy usage scheme. When it comes to reducing energy consumption, there is less reliance on a commodity over which a company has no price control, so potential future problems with energy scarcity, legislation, and prices can be mitigated.

9.2 Recommendations

This study recommends that the existence of energy expertise with energy management skills, existence of condition monitoring technologies, performing regularly energy audits and reducing skipping of maintenance will help to improve energy efficiency.

In addition, management should provide enough energy management skills to its people through trainings based on both operation and maintenance that aim at improving energy efficiency. The use of state monitoring technologies should be improved, and the necessary energy measurement equipment should be available for routinely monitoring of machine energy performance. An energy audit should be done to identify energy gaps and ensure that maintenance is not skipped and that all Original Equipment Manufacturer (OEM) recommendations are followed.

9.3 Specific Recommendation

Brewery industries have been specifically advised to clearly define, establish, and integrate system developed into existing business operation goals and how people will be taught energy awareness and skills. The companies should also hire or select from among the available employees the employee who will be in charge of all energy-related issues.

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