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Factors Influencing Total Productive Maintenance Implementation for Thermal Generation Plants

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ABSTRACT

This study accepts that the technical and administrative factors can amplify effective total productive maintenance (TPM) implementation at thermal generation plants. It is noted that there is a limited number of studies that have attempted to understand the subject of TPM implementation in the energy sector. Noting this shortcoming, the authors thought it crucial to generate empirical evidence on the factors influencing effective TPM implementation for thermal generation plants, with evidence from gas-fired plants. A sample of 88 respondents was selected and consulted. Data were collected through questionnaires and analyzed quantitatively by inferential statistics and qualitatively through thematic analysis using SPSS version 20.0. Confirmatory factor analysis (CFA) was performed through LISREL software version 8.0. On inferential analysis, correlation, regression and ANOVA were performed. Multiple regression analysis results indicate that administrative factors, including management support, TPM awareness, employee participation and strategic planning, positively and significantly influence TPM implementation. Also, technical factors comprising planned maintenance, autonomous maintenance, quality maintenance and early equipment management positively influence TPM implementation at thermal generation plants. The correlation coefficient for all factors was at least 0.6, and the p-value was less than 0.05, suggesting that the study's independent variables reliably predict the dependent variable. The additional factors influencing TPM implementation include training and education, organization of the workplace, root cause analysis and continuous improvement. From this juncture, the study concludes that effective TPM implementation in the energy sector, especially at thermal generation plants, can be accomplished if many administrative and technical factors are considered. These factors comprise management support, TPM awareness, strategic planning, employee participation, workplace organization, training and education, planned maintenance, autonomous maintenance, quality maintenance, early equipment management, continuous improvement and root cause analysis.

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INTRODUCTION

Total Productive Maintenance (TPM) is a system, tool or maintenance approach introduced to maintain and improve machine's lifetime by establishing different techniques (Nakajima, 1988). Such a maintenance strategy was introduced to improve the overall effectiveness of equipment (OEE), which is a function of all vital production parameters, i.e. performance, availability and quality of products or systems (Labiyi, 2019). TPM deals with identifying the causes of different types of losses to develop mitigation plans to reduce and maintain free-loss running behaviours.

The primary aim of TPM is to have sustainable performance, availability and best quality of products and to eradicate the causes of different types of losses (Chan *et al.*, 2005). TPM assists in reducing production waste, focusing on the maintenance of production equipment, in upsurging their operation and efficiency while warranting the quality of production due to averting the causes that lead to waste (Gherghea *et al.*, 2021). TPM comprises the following pillars: autonomous maintenance, focused improvement, planned maintenance, training and education, preventive maintenance, quality maintenance, office TPM, and development maintenance (Setiawan, 2021). According to Setiawan (2021), 5S is the foundation of the TPM house. TPM aims to achieve zero accidents, zero defects and zero breakdowns (Setiawan, 2021).

In Japan, TPM was introduced in early 1951, and Nippon Denso of the Toyota group was the first to implement this maintenance approach (Ahuja and Khamba, 2008). Since the introduction of TPM, different scholars worldwide have developed studies on TPM implementation concerning their field of work to achieve more results by adopting this maintenance approach. For example, Hafiz *et al.* (2012) developed and implemented the TPM concept in fertiliser industries, while Kuncoro (2018) studied TPM implementation for Nigerian manufacturing industries. On the other hand, Hafiz *et al.* (2012) observed TPM as a complex maintenance approach requiring a framework to guide its implementation. Likewise, Patil and Raut (2019) deployed TPM approaches and managed to reduce the maintenance problems by 50% using root cause analysis in the manufacturing industry.

Thermal power plants (TPPs) utilize nuclear materials or fossil fuels to generate most electricity globally (Coffel and Mankin, 2021). TPPs can be utilizing the gas turbine (GT), also known as the combustion turbine. The GT "is a rotary motor that removes energy from a hot gas flow generated in a stream of compressed air by combustion of gas or fuel oil" (Najjar and Abu-Shamleh, 2020).

The national policy on energy reform of 2003 was introduced to motivate the private sector to overcome monopoly in the electricity business. However, the Tanzania Electric Supply Company Limited (TANESCO) continues to dominate power utility services over other firms (Mbaiwa, 2003). The existing independent power producers (IPPs), such as Songas gas power plants, generate and feed electric power to the national grid owned by TANESCO (TANESCO, 2018). According to the report by TANESCO (2018), TANESCO has two major electricity generation sources: hydro and thermal power plants. Thermal power plants contribute 977.97 MW (63.5%) of the total generation, while hydropower plants contribute 561.84 MW (36.5%) of the total generation. This demonstrates that currently, TANESCO generation relies more on thermal generation than hydro plants (TANESCO, 2018). Apart from distribution and transmission losses contributing to TANESCO's underperform, other factors affect power generation. They include abrupt machines breakdown and failures, which may result to load shedding or total blackout (National Grid failure) due to variations in grid parameters (TANESCO, 2018).

Despite the efforts by TANESCO to overcome these challenges, a study by Malima (2012) indicates that customers have not been satisfied with the services provided by TANESCO due to frequent power cuts, which affect their daily economic activities. One of several reasons for that includes the lack of appropriate maintenance approaches in thermal generation plants, which are more susceptible to breakdowns due to their nature of operations.

The existing maintenance approaches applied by TANESCO are preventive and corrective maintenance, which involve only the maintenance team without the operators as far as Autonomous maintenance is concerned (Gustafson *et al.*, 2011). Autonomous maintenance should include the holistic involvement of the people in the machine's responsibilities. This maintenance approach underscores a gap between the maintenance team and the plant operator's team (Gustafson *et al.*, 2011). This approach may lead to higher maintenance costs and the recurrence of failures (Carnero and Novés, 2006). The TPM approach aims at overcoming these challenges through Autonomous maintenance practices and commitment to implementation (Madani, 1996).

There have been lots of previous work on TPM implementation. Bakri (2015) developed a TPM framework for Malaysia's automobile industries to investigate the effect of TPM implementation on small and medium industries. Bakri (2015) developed the TPM Framework by including an extensive implementation plan, which comprised eight pillars of TPM, employees' skill development linked with the equipment life cycle, and holistic involvement of business stakeholders. Kithinji (2016) studied the effect of TPM on thermal power plant productivity for the Kipevu hydropower plant. From Kithinji's (2016) study, it was revealed that there is a strong relationship between TPM implementation and productivity. TPM can upsurge productivity by reducing losses, improving quality through the reduction of defects and thus detecting them in the earlier stages.

Additionally, TPM can enhance productivity by reducing costs, improving the working environment, and increasing equipment reliability and availability. Another scholar is Ngugi (2015), who developed TPM practices framework and equipment effectiveness for Bamburi Cement Limited in Kenya. It was revealed from Ngugi's (2015) study that TPM ensures the sustainability of quality products and services.

Likewise, Gustafson *et al.* (2011) developed a TPM framework for underground mobile mining equipment in Tanzania. Gustafson *et al.* (2011) found that TPM is vital in mining because it eliminates waste from plummeting production time lost and machine failures. The TPM program's goal in the mining industry is to ensure the reliability and availability of the fleets of mobile equipment and process lines (Gustafson *et al.*, 2011).

Thus, minimising slow-running equipment and downtime adds maximum value at minimum costs (Gustafson *et al.*, 2011). Therefore, there is a need to investigate factors that influence TPM implementation in TANESCO's thermal generation plants. This study aims at examining variables to be used to develop a framework for the implementation of TPM at TANESCO's thermal generation plants.

CONCEPTUAL FRAMEWORK

This study envisages that administrative factors such as management support, awareness of staff on TPM, strategic planning, cultural change, cooperation and communication, training and education influence effective TPM implementation.

Furthermore, the study envisages technical factors such as planned, reliability-centred maintenance quality, autonomous, and the relationship between independent and dependent variables, as illustrated in Figure 1. Early equipment management to influence effective TPM implementation.

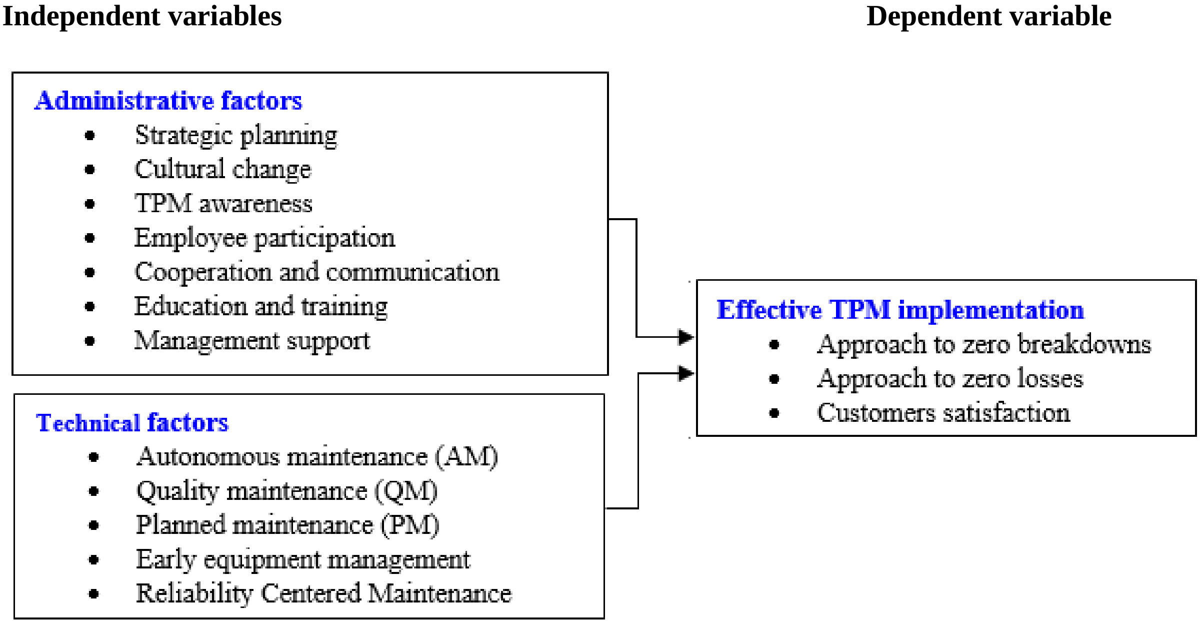

Figure 1: Conceptual framework for illustrating factors affecting TPM implementation.

METHODOLOGY

This study adopted a mixed study approach to gain the advantages of using quantitative and qualitative methods in data collection from Ubungo I and II thermal power generation plants. The study population comprises TANESCO staff working at Ubungo I and II gas-fired plants. This study targeted all cadre of staff, including top management and non-technical staff and technical staff such as plant managers, principal plant engineers, plant planning engineers, plant maintenance team, engineers, technicians, artisans, plant cleaners, accountants, human resources officers, procurement and safety officers. Using Cochran's formula, as cited by Taifa (2016), in the sample determination, the sample size of 88 respondents was optimum from the total population size of 112 staff of the selected study areas. The sample size for the known population was given by using equation (1).

$$n = \frac{N}{1 + Ne^2} \qquad (1)$$

whereby n stands for sample size, N = study population (112 employees) and e = marginal error which was assumed to be 5%. Therefore, the appropriate sample population used for this study was 88 respondents.

A stratified random sampling method was used in which the study population was grouped from heterogeneous populations into homogenous subsets. Then, the sample population was selected in each homogenous subset. This method was considered suitable for this study due to its unbiased nature, which ensures representation in each subset. Quantitative data collected through closed-ended questionnaires in the 5-point Likert scale (strongly disagree, disagree, neutral, agree and strongly agree) were analysed using multiple regression analysis with the aid of Statistical Package for Social Science (SPSS). On the other side, qualitative data collection was performed using open-ended questions incorporated in the questionnaire to supplement the results. Thematic analysis was deployed for qualitative data analysis, which grouped data into themes and presented descriptively through frequencies and percentages. Confirmatory factor analysis (CFA) was derived in this study with Linear Structure Relations (LISREL) software version 8.0.

RESULTS AND DISCUSSION

Demographic analysis

This study comprised both male [61(70.9%)] and female [25(29.1%)] respondents: about 39 respondents, equivalent to 45.4%, were aged between 40-50 years while the rest were aged 29-39 years [19(22.1%)], 51-60 years [19(22.1%)] and 18-28 year [9(10.4%)]. In this study, 21 respondents (24.42%) had an education level of certificate, 38 respondents (44.19%) had a diploma, and 26 respondents (30.23%) had an undergraduate degree, only 1 respondent (1.16%) with a master's level of education and none of them with PhD (0%). Two respondents, equivalent to 2.33%, have working experience of less than one year, 18 respondents (20.93%) had an experience of one to five years, 49 respondents (56.98%) had an experience of six to ten years, and 17 respondents (19.77%) have more than 10 years of experience. About 31 respondents (36.04%) were maintenance officers, followed by 30 plant operators (34.88%), 6 shift engineers (6.98%), 1 planning and 1 principal engineer, equivalent to 1.16% each. Furthermore, the target population comprised 2 safety officers, 2 human resource officers, 2 plant managers, 2 plant secretaries, equal to 2.33% each, while 3 respondents were accounting officers, procurement officers and plant cleaners, equivalent to 3.49% each. The respondents included secretaries and cleaners, even though the nature of their work does not involve any maintenance activities. This is because TPM involve 5S as one of the foundation concepts, and such philosophy includes everybody being accountable for maintaining the system. Implying that it has to be practiced in workplaces where workers understand the thinking behind 5S, and not perceive it as just the steps and tasks they are obliged to undertake.

Confirmatory factors analysis (CFA)

In this study, CFA was performed to identify key factors influencing TPM implementation and condense the variables into a small set to facilitate easier interpretation. CFA was derived in this study with a LISREL version 8.0. In this case, the study's independent variables' sub-variables were loaded into this system to obtain the variables were appropriate for further analysis. All independent sub-variables of the two predictor variables, including administrative and technical factors, were loaded into the software to perform CFA. In this study, a *t*-value greater than 1.96 was considered acceptable for further analysis, as Lewis and Lewis (2017) recommended.

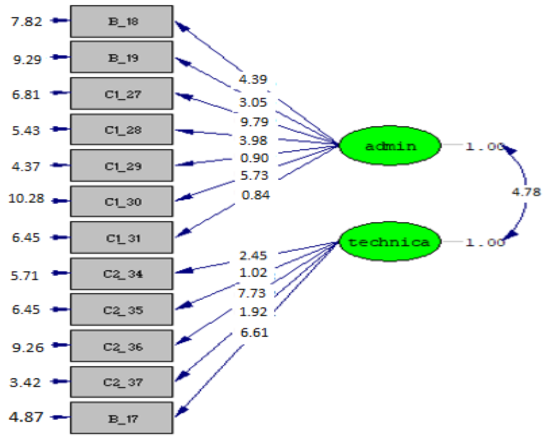

Figure 2: Confirmatory factor analysis

CFA for administrative factors

Figure 2 depicts the results for the CFA. As described in Figure 2 and Table 3, CFA results indicated that management support was the administrative factor with the highest *t*-value (9.79). At the same time, cooperation and communication was administrative factor with the lowest *t*-value (0.84). According to the rule of Lewis and Lewis (2017), values equal to 1.96 and above an acceptable scores for the *t*-value. This study retained 5 factors and dropped 2 factors that have not reached an acceptable level. The retained variable in administrative factors, includes strategic planning, training and education, management support, TPM awareness and employee participation. In contrast, cultural change, cooperation, and communication were dropped because they did not reach the acceptable score for *t*-values, as shown in Figure 2 and Table 3.

Table 3: CFA results for the administrative factors

Code	Items	*t*-value	Status
B_18	Strategic planning	4.39	Retained
B_19	Training and education	3.05	Retained
C1_27	Management support	9.79	Retained
C1_28	TPM awareness	3.98	Retained
C1_29	Cultural change	0.90	Dropped
C1_30	Employee participation	5.73	Retained
C1_31	Cooperation and communication	0.84	Dropped

CFA for technical factors

The CFA results indicated that autonomous maintenance was the highest *t*-value score (7.73). In contrast, reliability-centred maintenance was the technical factor with the lowest *t*-value score (See Table 4). In this study, three technical factors, including planned maintenance, autonomous maintenance and early equipment management, were retained for further analysis because they had a *t*-value above 1.96, as Lewis and Lewis (2017) recommended. Conversely, two factors, reliability-centred maintenance and quality maintenance were dropped because they did not reach an acceptable *t*-value score of 1.96, as shown in Table 4.

Table 4: CFA results for the technical factors

Code	Items	*t*-value	Status
C2_34	Planned maintenance	2.45	Retained
C2_35	Reliability centred maintenance	1.02	Dropped
C2_36	Autonomous maintenance	7.73	Retained
C2_37	Quality maintenance	1.92	Dropped
B_17	Early Equipment management	6.61	Retained

4.2 Inferential analysis

After the execution of CFA, inferential analysis was employed to define the nature of the relationship and significance of the predetermined independent variables to the dependent variable. However, only the retained factors after CFA were preceded for the inferential analysis. In this study, the correlation was used to determine the strength of the relationship between the variables, and multiple regressions were further used to establish the nature of the relationship. Furthermore, ANOVA was used to check the overall significance of the variables.

Correlation analysis results for administrative factors

This part shows the correlation between the independent and dependent variable(s). Taylor (1990) suggested that correlation coefficient (*rs*) ranging from 0.00 to 0.1 should be considered *very weak*, 0.20 to 0.39 (*weak*), 0.4 to 0.59 (*moderate*), 0.6 to 0.79 (*strong*), and 0.8 to 1.0 (*very strong*). In this context, the findings of this study indicated that the correlation coefficient for management support and TPM implementation was 0.626, and the *p*-value was 0.000. This implies that management support strongly correlates with effective TPM implementation. The findings also indicated that TPM awareness and TPM implementation coefficients were 0.724, and the *p*-value was 0.000, implying that TPM awareness is strongly and significantly correlated with effective implementation. Correlation results also indicated that the coefficients for strategic planning and TPM implementation were 0.740, and the *p*-value was 0.000, suggesting that strategic planning is strongly and significantly correlated with effective TPM implementation. It was also indicated that the correlation coefficient for employee participation and TPM implementation was 0.800, and the *p*-value was 0.000, suggesting that employee participation is very strongly and significantly correlated with effective TPM implementation. Moreover, correlation results indicated that coefficients for training and education and TPM implementation as the dependent variable were 0.680, and the *p*-value was 0.000, indicating a strong and significant correlation between training and education and TPM implementation. Table 5 presents these findings in detail.

Table 5: Correlation results

		1	2	3	4	5	6
1. TPM Implementation	Pearson Correlation	1					
	Sig. (2-tailed)						
	N	86					
2. Management support	Pearson Correlation	0.626**	1				
	Sig. (2-tailed)	0.000					
	N	86	86				
3. TPM awareness	Pearson Correlation	0.724**	0.556**	1			
	Sig. (2-tailed)	0.000	0.000				
	N	86	86	86			
4. Strategic planning	Pearson Correlation	0.740**	0.526**	0.605**	1		
	Sig. (2-tailed)	0.000	0.000	0.000			
	N	86	86	86	86		
5. Employee participation	Pearson Correlation	0.800**	0.522**	0.642**	0.674*	1	
	Sig. (2-tailed)	0.000	0.000	0.000	0.000		
	N	86	86	86	86	86	
6. Training and Education	Pearson Correlation	0.680	0.473	0.544	0.615	0.698	1
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	
	N	86	86	86	86	86	86
**. Correlation is significant at the 0.01 level (2-tailed).							

Regression analysis for administrative factors

Regression analysis scrutinises the relationship between a single dependent variable and several predictor variables (Baldua *et al.*, 2014). This research used regression analysis for each strong independent variable based on the regression model's assumptions. The purpose was to check to what extent independent variables affect or influence the dependent variable: management support, employee participation, training and education, strategic planning, and workplace organisation. So, the *F*-test was used to define the model's validity, while *R* squared was used to measure the model's goodness of fit. According to Morphet *et al.* (2014), when evaluating each independent variable, if the significant value (*p*-value) is less than .05, the variable makes a significant unique contribution to the prediction of the dependent variable. If greater than .05, the variable is not making a significant unique contribution to the dependent variables' prediction. Table 6 shows the coefficient of administrative factors obtained after the analysis.

Table 6: Coefficients for administrative factors

Model	Unstandardised Coefficients		Standardised Coefficients	T	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	.364	.241		1.506	.136		

Management support	.113	.051	.152	2.228	.029	.616	1.624
TPM awareness	.194	.068	.219	2.870	.005	.490	2.040
Strategic planning	.185	.065	.224	2.830	.006	.455	2.200
Employee participation	.327	.080	.358	4.077	.000	.371	2.698
Training and Education	.091	.070	.102	1.297	.198	.466	2.146

a. Dependent Variable: TPM Implementation

a) *Management support*: multiple regression analysis results indicated that management support positively and significantly influences effective TPM implementation at the selected thermal generation plants. This was because the *β*-value was positive (0.152), and the *p*-value was 0.029, less than 0.05. This implies that management support is vital on the issues concerning TPM implementation as top management has a big role in the decision-making, planning, and managing of fiscal resources. Hence, top management could decide upon adopting and implementing TPM; therefore, their support is highly necessary. These findings concur with the study by Tondato and Gonçalves (2013), who also revealed that management support has a huge significance on the effectiveness of TPM practices. As was noticed in the energy industry, TPM implementation in the manufacturing industry can also be effective if the management team is committed to supporting TPM practices, including a budget, plans and technical support.

b) *TPM awareness*: it was revealed that TPM awareness plays a great role in the effectiveness of TPM implementation. Multiple regression analysis results indicated that it positively and significantly influences effective TPM implementation (β=0.219, p=0.005). The qualitative findings obtained through open-ended questions added that TPM awareness greatly promotes employee participation in TPM implementation. Awareness of staff on TPM implementation can be improved through different strategies like employee communication, but training and education are the primary factors that can promote this. This is consistent with the findings of Ngugi (2015) that awareness of staff about TPM practices is vital as it amplifies employees' knowledge on the matter. Due to sustainable knowledge of employees on TPM practices, employees be on the frontline during TPM implementation; as a result, it contributes to its effective implementation.

c) *Strategic planning:* this study concedes that strategic planning is of vast importance to TPM implementation as the results through linear regression analysis demonstrated that it has a positive and significant influence on effective TPM implementation (β= 0.224, p= 0.006). Respondents who participated in this study added that having a strategic plan in place is vital as it provides a roadmap towards TPM implementation, and it answers the questions of where the company is, where it needs to go, and whether the company can reach the intended goals regarding TPM implementation. These findings align with Shaaban and Awni (2014) findings that strategic planning enormously contributes to the effective implementation of TPM as it emphasises senior and junior staff's commitment to a company towards successful TPM implementation.

d) *Employee participation:* TPM implementation requires the involvement of all staff and departments. This has been confirmed by multiple regression results, which indicated that employee participation has a positive and significant influence on the effective implementation of TPM at the studied thermal generation plants (β= 0.358, p= 0.000). This also implies that effective implementation of TPM becomes easier whenever there is employee participation. Consistent with qualitative results, respondents also declared that employee involvement is vital in implementing TPM successfully. Similarly, in their study, Singh and Ahuja (2013) emphasised that TPM implementation highly demands the involvement of employees, including technical and administration staff, in implementing TPM. All employees have a common responsibility to take good care of the plants and machines available in their working places as even unwanted things can lead to damages or breakdowns; hence employee participation can minimise these incidents.

e) *Training and education:* the results demonstrated that training and education have a positive but insignificant influence on effective TPM implementation at the selected plants (β= 0.102, p= 0.198). However, these findings do not concur with qualitative results as the sampled TANESCO employees suggested that training and education are significant variables towards achieving effective TPM implementation. The following are the popular and most preferred suggested areas to put much emphasis on training:
   i. Training on route analysis tools; techniques to cultivate the root cause of the problem, such as why-why analysis, fault tree analysis, TPM analysis, and others, should be known to both operators and the maintenance team.
   ii. Training on the approaches to continuous improvement (CI) involves knowledge of the criteria for CI, the steps to undertake this, and the outcomes for CI. This can also contribute to OEE's improvement through production efficiency because it discusses the step-by-step improvement analysis.

Model summary for administrative factors

This part provides the R-values. The R-value explains how well the whole model describes the data. In this case, the model explained 88% of the data. R square explains the extent to which the independent variables explain the variability of the dependent variable. So, 77.5% of the variability in TPM implementation was explained by the independent variables: management support, TPM awareness, strategic planning, employee participation, and training and education. In this study, the adjusted R square value was 76%. This means that the independent variables explained 76% of the total variability of the dependent variable. Table 7 explains these results in detail.

Table 7: Model summary for administrative factors

Model	R	R Square	Adjusted R Square	Standard error of the estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.880[a]	.775	.760	.44027	.775	54.281	5	79	.000

a. Predictors: (Constant), Training and Education, Employee participation, strategic planning, TPM awareness, Management support

ANOVA for administrative factors

This part presents the analysis of variance (ANOVA), thus providing statistics about the overall significance of the model's fit. By looking at the significant value, also known as the p-value, it is possible to know whether the study's independent variables explain the dependent variable. The ANOVA results indicated that the p-value is 0.000, less than 0.05 (Table 8). Such results signify that the study's independent variables, including management support, TPM awareness, strategic planning, employee participation and training and education, reliably explain the dependent variable, which was the TPM implementation. So, the model is statistically significant.

Table 8: ANOVA[a] for administrative factors

Model		Sum of Squares	Df	Mean Square	F	Sig.
	Regression	52.609	5	10.522	54.281	.000[b]
1	Residual	15.313	79	.194		
	Total	67.922	84			

a. Dependent Variable: *TPM Implementation*

b. Predictors: (*Constant*), *Training and Education*, *Employee participation*, *strategic planning*, *TPM awareness*, *Management support*.

Coefficients from the regression equations (2) and (3) demonstrate how effective various administrative factors can influence TPM implementation in an organisation, such as management support, TPM awareness, strategic planning, employees' participation and training and education. Therefore, these results demonstrate that the contribution of management support to the effective TPM implementation is 0.152 (15.2%), whereby it is related significantly with a *p*-value equal to 0.029, TPM awareness contributes to 0.219 (21.9%) significantly with a *p*-value equal to 0.005, strategic planning also bares its contribution to 0.224 (22.4%) whereby this relation is significant at *p*-value equal to 0.006, employees participation contributes to 0.358 (35.8%), and it relates significantly at *p*-value equal to 0.000. Finally, training and education contribute to the effective TPM implementation by 0.102 (10.2%), and the relationship is significant at a *p*-value of 0.198.

$$Y_a=\beta_{0a}+\beta_{1a} X_{1a}+\beta_{2a} X_{2a}+\cdots+\beta_{5a} X_{5a}+\varepsilon_a \quad (2)$$

$$Y_a=.364+.152X_{1a}+.219X_{2a}+.224X_{3a}+.358X_{4a}+.102X_{5a}+.05 \quad (3)$$

whereby; Y_a = TPM implementation, β_{0a} = constant, (β_{1a} to β_{5a}) = regression coefficient of independent variables, ε= error term, X_{1a}= management support, X_{2a} = TPM awareness, X_{3a} = strategic planning, X_{4a} = employee participation and X_{5a} = training and education.

Correlation analysis results for technical factors

The results showed that the correlation coefficient for quality maintenance and implementation of TPM was 0.884, and the *p*-value was 0.000. This implies that quality maintenance has a very strong and significant correlation with effective TPM implementation. The findings also indicated that the coefficients for autonomous maintenance and TPM implementation were 0.756, and the *p*-value was 0.000, implying that autonomous maintenance is strongly and significantly correlated with effective TPM implementation. Correlation results also indicated that coefficients for early equipment management and TPM implementation were 0.734, and the *p*-value was 0.000, suggesting that early equipment management is strongly and significantly correlated with effective TPM implementation. Also, correlation results indicated that the coefficients for planned maintenance and TPM implementation were 0.784, and the *p*-value was 0.000, indicating a strong and significant correlation between planned maintenance and TPM implementation. Table 9 presents these findings in detail.

Table 9: Correlation analysis results

		1	2	3	4	5
1. TPM Implementation	Pearson Correlation	1				
	Sig. (2-tailed)					
	N	86				
2. Autonomous maintenance	Pearson Correlation	0.756**	0.607**	1		
	Sig. (2-tailed)	0.000	0.000			
	N	86	86	86		
3. Early equipment management	Pearson Correlation	0.734**	0.495**	0.805**	1	
	Sig. (2-tailed)	0.000	0.000	0.000		
	N	86	86	86	86	
4. Planned maintenance	Pearson Correlation	0.784**	0.665**	0.455**	0.503*	1
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	
	N	86	86	86	86	86
**. Correlation is significant at the 0.01 level (2-tailed).						

Regression analysis for technical factors

Regression analysis analyses the relationship between a single dependent variable and several predictor variables (Baldua *et al.*, 2014). According to Gakure (2013), when evaluating independent variables, if the significant value (*p*-value) is less than .05, the variable makes a significant unique contribution to the prediction of the dependent variable. If greater than .05, the variable is not making a significant unique contribution to your dependent variables' prediction. So, the *F*-test defined the model's validity while R squared measured the model's goodness of fit. Table 10 shows the coefficient of administrative factors obtained after the analysis.

Table 10: Coefficients of technical factors

Model	**Unstandardised Coefficients**		**Standardised Coefficients**	**T**	**Sig.**	**Collinearity Statistics**	
	B	**Std. Error**	**Beta**			**Tolerance**	**VIF**
(Constant)	.162	.124		1.309	.194		
Quality maintenance	.428	.037	.508	11.694	.000	.430	2.325
Autonomous maintenance	.117	.047	.132	2.482	.015	.286	3.497
Early equipment management	.208	.043	.243	4.809	.000	.319	3.131
Planned maintenance	.211	.032	.264	6.578	.000	.504	1.985

a. Dependent Variable: TPM Implementation

Planned maintenance has been acknowledged as an important pillar of TPM practice due to its contribution to maintaining and expanding the lifespan of machines as it encourages better use of machine history and condition in estimating equipment maintenance schedule ($\beta = 0.264$, $p = 0.000$). Planned maintenance: multiple regression results demonstrated that planned maintenance has a positive and significant contribution to the effectiveness of TPM implementation at thermal generation plants. These findings concur with Wangwe *et al.* (2014) that all companies that aim to achieve effective TPM practices should adhere to planned maintenance. The machine should be maintained, the history of the machine, time-to-time checkups of the condition of the machines and having a proper schedule guiding machine maintenance greatly contribute to the minimization of uncertainties such as breakdowns.

Autonomous maintenance: it was stated that successful TPM implementation highly depends on autonomous maintenance. The findings through multiple regression analysis indicated that autonomous maintenance has a positive and significant influence on effective TPM implementation, such that β= 0.132 and *p*-value = 0.015, which is less than 0.05. In the same way, in their study, Agustiady and Cudney (2018) revealed that autonomous maintenance is an important pillar of TPM that companies which target successful implementation of TPM should adopt. This is because autonomous maintenance emphasizes the involvement of each staff in the company in machine maintenance, which makes each company employee involved in taking care of machines to increase the machine lifespan.

Early equipment management: Like other TPM pillars, including planned, autonomous, and quality maintenance, it was confirmed that early equipment management has a positive and significant influence on effective TPM implementation (β= 0.243, *p*= 0.000). The involvement of technical staff in the procurement process of machines from the beginning contributes to quality assurance of the machines as the technical staffs have better knowledge about the machine specifications, models, brands and so on. So, this variable should be given the same importance as other TPM pillars, such as autonomous and quality maintenance, which have been proven to significantly contribute to effective TPM practices.

Model summary for technical factors

This part provides the R-values for the model performance. The R-value explains how well the whole model regarding the influence of technical factors on effective TPM implementation describes the data. In this case, the model explained 96.7% of the data. R square explains the extent to which the independent variables explain the variability of the dependent variable. So, 93.5% of the variability for the TPM implementation was explained by the independent variables: quality maintenance, autonomous maintenance, early equipment management, and planned maintenance. In this study, the adjusted R square value was 93.2%. This means that 93.2% of the total variability of the dependent variable was explained by the independent variables (see Table 11).

Table 11: Model summary for technical factors

Model	R	R Square	Adjusted R Square	Standard error of the estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.967[a]	.935	.932	.23498	.935	287.517	4	80	.000

a. *Predictors: (Constant), Planned maintenance, Early equipment management, Autonomous Maintenance, Quality maintenance*

ANOVA for technical factors

This part presents the analysis of variance (ANOVA). This section provides statistics about the overall significance of the modelbeing fit. By looking at the significant value, also known as the *p*-value, one can know if the study's independent variables explain the dependent variable. The ANOVA results indicated that the *p*-value is 0.000, less than 0.05. This tells us that the study's independent variables reliably explain the dependent variable, which was the effective TPM implementation. Table 12 describes ANOVA for the technical factors in detail.

Table 12: ANOVA[a] for technical factors

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	63.504	4	15.876	287.517	.000[b]
	Residual	4.417	80	.055		
	Total	67.922	84			

a. Dependent Variable: TPM Implementation

b. Predictors: (Constant), Planned maintenance, Early equipment management, Autonomous maintenance, Quality maintenance

From;

$$Y_t=\beta_{0t}+\beta_{1t} X_{1t}+\beta_{2t} X_{3t}+\cdots\ldots+\beta_{4t} X_{4t}+\varepsilon_t \quad (4)$$

$$Y_t=.162+.264X_{1t}+.508X_{2t}+.132X_{3t}+.243X_{4t}+.05 \quad (5)$$

where by Y_t = effective TPM implementation, β_{0t} = Constant, (β_{1t} to β_{4t}) = regression coefficient of independent variables, ε_t = error term, X_{1t}= planned maintenance, X_{2t}=quality maintenance, X_{3t} = autonomous maintenance, and X_{4t} = early equipment management. Coefficients from the regression model (equations 4 and 5) demonstrate how various technical factors can influence the effective TPM implementation in an organisation, such as planned maintenance, quality maintenance, autonomous maintenance, early equipment management and continuous improvement. Therefore, the results demonstrate that the contribution of planned maintenance to the effective TPM implementation is 0.264 (26.4%), which is related significantly with a *p*-value equal to 0.000. Quality maintenance contributes significantly to 0.508 (50.8%), with a *p*-value equal to 0.05. Autonomous maintenance contributes by 0.132 (13.2%), whereby such a relation is significant at *p*-value = 0.015. Early equipment management contributes by 0.243 (24.3%), and the relationship is significant at a *p*-value of 0.000.

Thematic analysis for qualitative findings

Thematic analysis was used to analyse qualitative data collected through open-ended questions incorporated in the questionnaires. Respondents were asked to suggest administrative and technical factors contributing to effective TPM implementation at the thermal generation plants. Their suggestions were coded and presented descriptively in Figures 3 and 4. According to the findings through thematic analysis, management support was the administrative factor most frequently suggested by sample TANESCO staff, pointed out by 24.2% of respondents. This was followed by TPM awareness (20.9%), training and education (17.4%), employee participation (15.1%), strategic planning (12.8%) and workplace organisation (9.3%). Several factors were also confirmed by multiple regression analysis results, including management support, TPM awareness, strategic planning and employee participation. This implies that the study's quantitative and qualitative findings concur. In thematic analysis findings, workplace organisation was observed to be the factor supported through qualitative findings only. These results resembled the result from the study completed by Hafiz *et al.* (2012) on the implementation of the total productive maintenance concept in a fertilizer process plant. Figure 3 elaborates on these findings.
The findings through thematic analysis indicated that autonomous maintenance was the technical factor proposed by most respondents (30.2%) to contribute enormously to effective TPM implementation at TANESCO thermal generation plants. The findings also

indicated that planned maintenance is the most frequent factor suggested by respondents behind autonomous maintenance, as 19.8% of them proposed that planned maintenance contributes to effective TPM implementation at the selected plants. Other factors proposed by respondents include quality maintenance (15.1%), continuous improvement (12.8%), root cause analysis (RCA) (11.6%) and early equipment management (10.5%) (see Figure 4). In thematic analysis, technical factors like continuous improvement and RCA were observed to be the additional factors supported through qualitative findings since the rest of the factors were also supported through quantitative findings.

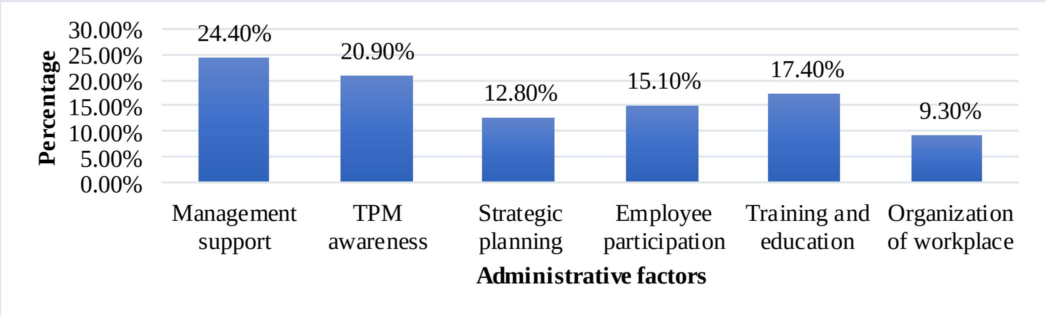

Figure 3: Ranking of administrative factors

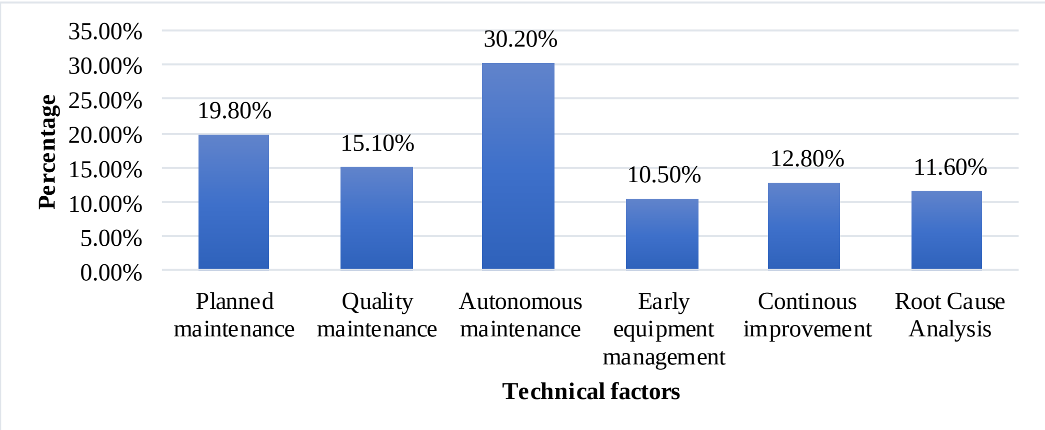

Figure 4: Ranking of technical factor

CONCLUSION AND RECOMMENDATION

Concluding remarks

Twelve variables were confirmed to be useful in achieving effective TPM implementation and were witnessed to positively affect TPM implementations. The TPM implementation assists in achieving zero breakdown and losses, availability of the machine, improved revenue collection and customer satisfaction, etc. The obtained variables incorporate technical and administrative factors, making it clear that TPM is not merely a 100% technical issue or a single departmental issue.

A proactive maintenance strategy that enhances the performance of thermal generation plants in the energy sector requires considering the twelve variables proved in this study to be important in achieving effective TPM implementation. These variables include management support, TPM awareness, employee participation, organisation of the workplace, strategic planning, training and education, planned maintenance, autonomous maintenance, quality maintenance, early equipment management, continuous improvement and root cause analysis.

Recommendation

The study recommends that thermal generation plants adopt more proactive maintenance strategies, including TPM. TPM should be adopted because it has a wider scope, including organisation's technical and administrative factors. As noted in this study, administrative factors, including management support, TPM awareness, employee participation and strategic planning; while the technical factors comprising planned maintenance, autonomous maintenance, quality maintenance, and early equipment management positively influence TPM implementation at thermal generation plants. The additional factors influencing TPM implementation include training and education, organisation of the workplace, root cause analysis and continuous improvement. The study, therefore, emphasizes the importance of implementing the above factors to accrue the benefits of TPM.

Implication to practice

Thermal power plants can use the information provided by this study to improve generation. As one of the key objectives of TPM is to attain improved productivity, this study entails an improved number of units if the influencing factors confirmed by the study are adopted and effectively implemented. This study is considered the foundation for other TPM research in Tanzania. A gap in TPM research in Tanzania must be fixed by developing several relevant types of research to emphasise TPM awareness. This study facilitates the improvement of electricity services through electricity generation due to productivity improvement, as stated by Tondato and Gonçalves (2013).

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