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Machine Maintenance Type and Quality of Output: Evidence from Ghanaian Manufacturing Firms

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ABSTRACT- The need to manage machine maintenance effectively has gained more importance due to the high rate of changing operational technologies, changing market demands, increased emphasis on employee safety, and new environmental legislation. To demonstrate the purpose of maintenance in the manufacturing value chain, the study sought to investigate the relationship between machine maintenance type and quality of output as well as to establish whether machine maintenance contributes to quality of output among Ghanaian manufacturing firms. Data was collected from 150 manufacturing firms in Tema and Accra Metropolis by using questionnaire and analyzed with SPSS and SmartPLS software. The findings showed significantly direct relationship between all the maintenance types, except corrective maintenance, and quality of output. Therefore, if a company minimizes breakdown maintenance, quality defects are also minimized. Hence, adopting preventive maintenance help reduce cost of repairs and unplanned stoppages in the production process.

Keywords: Machine Maintenance Type; Quality; PLS-SEM; Manufacturing.

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1. INTRODUCTION

The era after World War II saw increased mechanization due to industrial labour shortages and a rise in demand for different products. Availability, reliability, longevity of machines and cost, therefore became significant considerations for achieving business goals (Alsyouf, 2007). Losing a day's output due to unplanned stoppages can only be recovered by incurring extra costs such as overtime working, rework, and sometimes loosing valued clients to competitors. It is therefore important for manufacturing firms to incorporate the maintenance of machines and manufacturing capacities into their customer satisfaction policies (Aziz and Khalid, 2014).

Recent developments have shown revolutionary progress in areas of quality improvement and machine maintenance. Over the last few decades, improving the level of quality has gradually become a significant growth factor in most organizations. Widely and constantly encountered everywhere, quality has become omnipresent; it touches every industry. Greame (2011) argued that quality can be defined in various ways based on the context in which it is used. Defoe and Juran (2010) defined it as the 'fitness for purpose' and by Crosby (1979) as the conformance to specifications. Others have defined it with respect to meeting and or exceeding the expectations of customers and producing superior value (Feigenbuam, 1991; Geotsch and Davis, 2010). Understanding quality therefore can and should be associated with achieving or exceeding expectations, meeting requirements that had not been agreed on with clients, but once offered satisfies everyone.

In the manufacturing set-up, machines and equipment are prone to wear and tear during periods of usage and even when idle they can rust. Hence regular maintenance is required to improve their functionality and to enhance their efficiency (Bagshaw, 2017). It has therefore become very important for manufacturing companies to adopt machine maintenance practices and in particular, implementing an appropriate maintenance strategy (Raut and Raut, 2017). According to Ahuja and Khamba (2008) maintenance is any activity that is critical for the retention, or the restoration of a machine or equipment to the specified functional state to enable it to achieve its maximum useful life. It can therefore be seen as a series of actions in which the working condition of machinery or plant are kept in good condition to be able to produce maximum output at its optimum level of operation.

Recently, business dynamics are rapidly and constantly evolving. Markets face complex customer needs, which require higher quality and shorter delivery times, all at lower prices (Ben-Daya and Duffuaa, 1995). According to Alsyouf (2007), 'the conventional wisdom of embracing the concept of economy of scale is losing followers'. This is because a growing number of businesses have moved to lean manufacturing, just-in-time production, and six-sigma programs. These changes have highlighted a shift from emphasizing volume concentration to quicker response, waste elimination, and defect prevention. Consequently, the timely supply of products and services to customers in such demanding environments will create problems if machine breakdowns, speed loss, and erratic process yields are not eliminated. To sustain these operational strategies, the installation of the right machines and equipment, optimizing their maintenance and the efficient deployment of employees to perform the maintenance activities are critical factors. For years, quality and maintenance have been viewed as two important factors of company productivity though they are always emphasized separately. While the cost of machine maintenance is still given prominence, quite some studies have highlighted the importance of machine maintenance to manufacturing companies' total productivity and financial gains (Carter, 2001; Al-Najjar 2000; Kutucuoglua et al., 2001, Al-Najjar and Alsyouf, 2004). Though these attempts are appreciable, existing literature on the relationship between machine maintenance type and the quality of output in Ghana and globally are limited. Therefore, there is the need to examine the relationship between machine maintenance type and quality of output as well as to establish whether machine maintenance contributes to quality of output among Ghanaian manufacturing firms.

1.1 Manufacturing in the Ghanaian Context

Manufacturing industries refer to those businesses engaged in the processing and production of goods; they are either engaged in the production of new items or in adding value to semi-processed goods (Fenny, 2017). Final goods can serve as either finished goods for sale to customers or as intermediate goods that can be used in other production processes. According to Weber (1909), manufacturing can be seen as industrial processes that transform raw materials into finished goods on a large scale. The Ghana Statistical Service described manufacturing as a variety of activities involved in the production of goods and services (Ghana Statistical Survey, 2015).

Ghana's industrial sector which is made up of mining and quarrying, electricity, food processing, aluminium smelting, pharmaceutical, petroleum, water and sewerage has not been performing as expected over the past decade. The industry value added as a percentage of GDP has been declining from 34.09% in 2013 to 29.74% in 2020. This decline to some extent has contributed to an unprecedented level of unemployment in the country and poses a big threat to the socio-economic development of the country. Activities in the manufacturing sector include, but are not limited to the production of textiles, cement, chemicals and pharmaceuticals, processing of food and beverages, metals and wood products, and petroleum refinery.
According to the Association of Ghana Industries indicator report (2011), rivalry from imported goods which is a big challenge faced by businesses in Ghana's manufacturing sector in recent times can be linked to the poor performance of the sector (Ministry of Trade and Industry, 2011). Similarly, other factors that have also been attributed to the abysmal performance of the manufacturing sector are problems with land acquisition, high cost of capital, limited medium and long-term financing, unreliable power supply, and weak infrastructural support for sector development among others. In response to these challenges, several strategic interventions have been outlined by the government to create an enabling environment, with emphasis on manufacturing and exports. Among these is the National Industrial Revitalization Program with the stimulus package for industries (Ministry of trade, and Industry, 2014). Key institutions have also been put in place to assist manufacturing companies and notable among them is the Ghanaian Enterprise Development Commission (GEDC) and the Office of Business Promotion (Abor & Quartey, 2010).
Ghana's latest industrialization policy is currently aimed at creating an industrial architecture focused on value-added production of its natural resources through an accelerated industrial growth plan driven by the private sector (Ministry of Trade and Industry, 2011).

1.2 Quality in the Ghanaian context

The competitiveness in the global environment today puts a great deal of pressure on manufacturing firms to achieve world-class results (Miyake and Enkawa, 1999). In order to achieve this, many manufacturing companies are making efforts to boost efficiency, quality, and to reduce cost altogether.

In the past few years, quality management has changed from just monitoring and inspection phenomenon to talking more about quality plans and strategies to implement them and seeing quality as being equivalent to customer satisfaction. Quality has therefore become an overall mechanism beginning with customer demands as inputs and ensuring that an organization offers goods and services that meet or exceed these demands in the end.

Customers, governments, the general public, and stakeholders around the world are demanding companies in today's highly intensive competitive international market, to adopt product certification that offers the assurance of consistent quality product, waste reduction, environmental pollution prevention, safety for employees, and health of consumers. According to Osei et al. (2012), the knowledge of quality management among Ghanaian multinational companies with some expatriate leadership is high and they perform quite well. However, with similar dedication and resource base, these companies still fall behind their foreign counterparts. This shows that the development and effective use of both voluntary and mandatory production standards is important in promoting quality in Ghana's manufacturing sector. This is to assure consumers of their confidence and safety in products. Although voluntary process standards are established by consensus among relevant stakeholders effectively to provide a basis of evaluating the quality of goods and processes, legal regulations are also applied by governments to ensure the security and health of consumers and the environment.

Empowered by the Standards Authority Act 1973 (NRCD 173), the Ghana Standards Authority operates a product certification scheme that offers third party certification marks to companies who show that they have adopted and maintained an effective product certification in their operations and processes in accordance with the standards. Acquiring this mark therefore requires the determination of product compliance with the set standards through the sampling of products, initial testing, and evaluation of the company's quality management processes.

Subsequently, the quality of the product is constantly monitored through close observation of the companies' quality management systems, factory sample testing, and monitoring in the open market (Ghana Standard Authority, 2017).

In addition, the Ghana Standards Authority in conjunction with the Association of Ghanaian Industries (AGI), established the National Quality Awards (NQA) in 2017 which has become one of the country's most respected and recognizable awards over the years. The award scheme which rewards only locally owned Ghanaian manufacturing and service delivery firms for innovation and excellence in the implementation of internationally approved quality standards has consequently increased the awareness of the manufacturing and service community and the general public on the need for standardization (Ghana standard authority, 2017). It is also a strategic way by which the GSA has promoted itself to ensure that the quality of products and safety of consumers are preserved in the country.

2. LITERATURE REVIEW

Machine maintenance and quality are topics that have seen quite a number of theoretical interests in literature over the years (Kamau, 2014). Some of the theories that form the basis of this study are Theories (principles) of quality management; the systems theory, theory of constraints, and the transactional cost theory.

2.1 The Principles of Quality Management

The principles (theories) of quality management expounded by quality philosophers such as Deming (1995), Juran (1992), Crosby (1990), and Ishikawa (1990) include continuous improvement, employee involvement in decision making, leadership, paying attention to customer demands, and mutually beneficial relationships with suppliers. These concepts are also related to key factors influencing maintenance management activities such as maintenance types employed, policy deployment and organization, maintenance planning and scheduling, training, etc. (Al-Najjar and Alsyouf, 2004).

2.1.1 Systems Theory

The Systems theory views systems as input or output models, where the energy coming from the output reactivates the system (Katz and Kahn, 1966; Parsons, 1977). That is, the inputs are taken through processes to be transformed to outputs. The outputs are then compared with the objectives and feedback is sent back to inputs to enhance the improvement of efficiency and productivity of the system (Bertalanffy, 1968). Visser (1998) applied this theory in maintenance management. According to him, maintenance management is the system and the inputs were labour, materials, spares, information and tools. The system's output includes machine availability and reliability, safety, and profits.

2.1.2 Theory of Constraints

There is no doubt that processes and systems are in one way or the other constrained by bottlenecks. The Theory of Constraints (TOC), an extension of the systems theory, is meant to guide the effective optimization of processes and systems by eliminating these bottlenecks (Kirkwood and Mech, 2006). It is made up of management decision making tool for problem solving known as thinking processes, intended to identify and eliminate process and system constraints. According to Eliyahu (1984), the TOC also helps to address the questions: what should be changed, what it should be changed to, and how to trigger the change. In the same regard, machine maintenance practices can be enhanced by identifying system or process constraints that need to be changed, what it should be changed to, and the procedure for causing the change.

The theory also asserts that the goal of a firm should be able to maximize profits by increasing output, reducing inventory and reducing operating costs (Kamau, 2014), and at the same time not compromising on quality. When applied to equipment maintenance, the benefits include the development of a sound machine maintenance strategy which will lead to the improvement in machine availability and reliability, cost reduction, and the completion of work more efficiently (Kirkwood and Mech, 2006).

2.1.3 Transaction Cost Theory

Last but not least, the Transactional Cost theory postulates that a firm survives or is successful because of its capacity to economize on the cost of its market-oriented production (Slater and Spencer, 2000; Kamau, 2014). Applied to machine maintenance, this theory agrees that, firms need to reduce their cost of production by reducing machine stoppages, downtime, overtime, scrap, and rework to be efficient and remain competitive in the chosen market (Al-Turki, 2011).

2.2 Overview of Machine Maintenance

The demand for effective machine maintenance has greatly increased due to global trade and the increasing levels of operations innovation. Over the years, maintenance has often been viewed particularly within the manufacturing sector, as a cost-driving requirement. A study conducted by Alsyouf (2004) found that majority regarded machine maintenance and all its related activities as a cost center. Similarly, Maggard and Ryne (1992) indicated that the cost of machine maintenance can be said to range between 10 and 40 percent of the overall production cost of a company. Nonetheless, authors have highlighted the importance of machine maintenance in improving efficiency and profitability of production processes (Al-Najjar, 2000; Waeyenberg and Pintelon, 2002; Mitchell et al., 2002). This suggests that machine maintenance could generate profits for manufacturing firms and should no longer be considered only as cost.

In Ghana, several policies have been adopted over the years to put the country on the path of industrialization. Currently, the government of Ghana has introduced the Coordinated Programme of Economic and Social Development policies for the period between 2017 and 2024, which encapsulates the vision for accelerated development of the country (Ministry of Trade and Industry, 2018). At the centre of the program are industrialization and value addition, as a basis for the country to grow out of poverty and move it to the desired levels of development. Some special initiatives have been lined up under the program; amongst them is the One District One Factory (1D1F) policy.

As an expression of economic development, the objective of the 1D1F program is to set up at least one factory or enterprise in every district of Ghana to accelerate the development of the various local areas and create jobs for the youth. The policy aims to transform the economic structure of Ghana from its dependence on the production and export of raw materials to an integrated and industrialized one which adds value to the raw materials, and which is primarily driven by the private sector. Some factories established so far include the Komenda-Edina-Eguafo-Abrem pineapple and orange processing factory, a factory for the processing of starch (cassava) in the Fanteakwa District. In Tema is a cashew processing factory, and in Ningo-Prampram, an avocado processing factory (Ministry of Trade and Industry, 2018).

Without a doubt, growing the manufacturing base and producing products (that can be exported) that meet international quality standards is of vital importance to the economy. Thus, the 1D1F policy is an outstanding initiative for industrialization and needs to be looked at critically with regards to the sustainability of the production process and to be able to achieve its objectives.

Notwithstanding the many expected benefits of industrial development (1D1F policy), the lack of well-established and sound production processes, technology to ensure innovation and maintenance support, etc. for the industries will mean they will not be in operation for a long time. Hence, to propel the manufacturing sector towards rapid growth and global competitiveness, manufacturers must make use of any available alternative in terms of the best technology, innovation, and strategy to be able to produce at full capacity and at a reduced cost.

The health of machines, therefore, can describe the strength of a manufacturing firm, aside from its human resources. In this sense, the availability and reliability of machines are very crucial in the production process. This implies that machines require regular and proper maintenance to be able to produce products to meet desired specifications. This will in turn guarantee quality output and reduced waste, all things being equal. Ensuring the efficiency of machines can therefore increase production volumes and offer cost competitiveness (reduced cost in the form of scrap, rework, refunds, overtime, etc.) that will make the products affordable for households to patronize. This can lead to increasing demand, all things being equal, and employees will get to keep their jobs as well.

2.3 Classification of Machine Maintenance Types

According to Karande and Chakraborty (2013), the major capital costs of the manufacturing sector are equipment and machinery, effective equipment optimization, and maintenance. The purpose of machine maintenance is to keep machines in good condition in order to improve their availability (Swanson, 2001). In this sense, machine maintenance has become an essential and integral part of improving quality, productivity, and plant production strategy (Kumar et al., 1999; Ahmed et al., 2004).

According to Roup (1999), different organizations have adopted different maintenance strategies to enhance the effectiveness of maintenance on machines. Various types of maintenance have been identified in literature (Ribeiro, 2011). However, the classifications of these maintenance types are not in uniformity. According to Veldman et al., (2011) machine maintenance approaches are either planned or unplanned.

2.3.1 Planned Maintenance

In general, planned maintenance (also known as proactive maintenance) are all activities that include planning, recording and monitoring all work done to ensure that a plant is kept at its acceptable maintenance levels. This type of maintenance improves the day to day maintenance systems and ensures that maintenance activities are planned in advance. Planned maintenance uses information gathered on previous maintenance to make effective time and cost estimates which bring about improvement in time used for maintenance and cost savings (Gopalakrishman and Bannerji, 2004)).

Planned Maintenance can be divided into two broad types: preventive and predictive maintenance. Under preventive maintenance is constant interval, aged-based and imperfect maintenance. Condition Based (CBM) and Reliability Centered (RCM) maintenance types are also predictive maintenance types.

2.3.2 Preventive Maintenance (PM)

PM is any maintenance activity that is planned or scheduled and is carried out before the occurrence of machine failure with the intent to avoid or reduce machine breakdowns and to mitigate the effects of breakdown should it occur (Dilworth, 19992; Wild, 2002). The advantages of this practice are that it reduces the likelihood or rate of machine breakdowns, increases machine availability, improves machine efficiency, and reduces the amount of work done by maintenance staff. PM is also known to increase productivity and safety of the workers (Murthy et al., 2005).

2.3.3 Predictive Maintenance

According to Mobley (2008), predictive maintenance is a type of maintenance that applies periodic assessment of the current working conditions of machinery, manufacturing processes, and plant management functions to maximize the overall activity of machinery. The purpose of this maintenance is to be able to anticipate an imminent failure before they occur, thereby preventing failures that are expensive and can even cause health or safety risks (Gopalakrishnan and Banerji, 2004). Predictive maintenance can be achieved by monitoring the condition of machines for remedial maintenance actions to be taken when conditions deviate from the norm; for example, if noise and vibrations have increased (Pannerrselvam, 2009). This maintenance type can identify most factors that restrict the effectiveness and productivity of the entire plant or system if implemented effectively (Adjaye, 1994). To derive the benefits of predictive maintenance, the output which is data or information gathered should be implemented effectively (Zhou et *al*., 2006; Mobley, 2008, Murthy et al., 2005).

2.3.4 Unplanned or Reactive Maintenance

Unplanned maintenance includes activities such as repair, replacement, and restoration of a machine after a failure has already occurred in order to return it to its minimum operable condition. According to Mobley (2004), activities that are performed under this maintenance are mostly event-driven. The major types under unplanned maintenance tasks are emergency and corrective maintenance.

2.3.5 Corrective Maintenance

This is a type of unplanned or reactive maintenance which is normally done when a breakdown has occurred (Pannerrselvam, 2009). The objective of corrective maintenance is to restore a piece of machinery that has stopped meeting its acceptable condition (Gopalakrishman and Banejerji, 2004).

2.3.6 Breakdown or Emergency Maintenance

Breakdown maintenance, also known as emergency maintenance is undertaken when machinery demands immediate attention to keeps it running. This maintenance type is the most intrusive as it disrupts the production process, draws technicians away from their normal jobs, and reduces compliance to schedule. In extreme cases, emergency maintenance may prevent organizations from meeting their schedule depending on the extent of damage, time spent on repairs, spare parts availability, and the level of importance of machinery. The various types of maintenance as discussed have been illustrated below in *figure 1*.

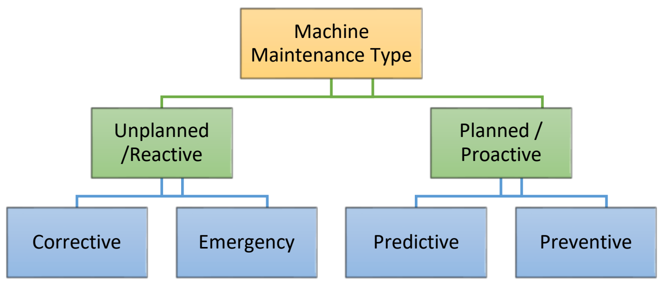

Figure 1: Maintenance Types Classification
*{**Source:** Authors' Own Construction}*

According to Telang and Telang (2010), though there are other types of maintenance types (deferred maintenance, routine maintenance, productive maintenance, improvement maintenance, contract maintenance *etc.*), planned and unplanned maintenance types are commonly used among manufacturing firms.

3. METHODOLOGY

The study employed a cross-sectional survey design; this involves collecting and analyzing data findings to answer questions concerning the current status of the subject. The choice of survey design best suits this research since surveys are characteristically quantitative in nature and have a high ability to produce outcomes that is reflective of the whole public (Suanders et *al*. 2007:134). The target population for this study is managers of maintenance, operations, and quality departments of registered manufacturing companies in Ghana. Using information from Ghana National Chamber of Commerce and the Association of Ghana Industries databases, 150 manufacturing firms were selected for this study based on their type of ownership (state-owned, private local, and private foreign companies). From the 150 firms, 1 respondent each was selected from maintenance, operations, and quality departments. Convenience and purposive sampling techniques were used to select manufacturing companies and respondents for this study. The managers were purposefully selected for the study since they possess more knowledge about the topic and will contribute meaningfully to the study. Consideration was given to those located in the Greater Accra region specifically, Tema and Accra since the region has been the focal point of industrial growth in Ghana and accounts for 23.4 percent of all manufacturing establishments in Ghana; with most of these establishments concentrated in Tema and Accra Metropolis (GSS, 2015). Thus, it is expected to be a fair representation of the whole population. Structured questionnaire was the main tool for data collection. Data obtained from respondents were analyzed with the help of Statistical Package for Social Sciences (SPSS) version 25 and SmartPLS 3 software. The first part of the analysis involved descriptive analysis. Bar graph, tables showing frequencies, percentages, and mean scores were descriptive statistical tools that were generated with the help of the SPSS software.

To achieve the purpose of this study, which is to identify the relationship between machine maintenance type and quality of output, Structural Equation Modeling (SEM) was used. Thus, with the help of Partial Least Squares Structural equation modeling, inferential statistics was adopted to examine the hypothesis and also draw conclusions about the population based on the data collected. According to Hair et al. (2010), SEM is a form of multivariate analysis technique that combines multiple regressions and factor analysis to examine structural relationships. PLS-SEM is a preferred choice because of its ability to analyze several exogenous latent variables with endogenous latent variables using path analysis (Monecke and Leisch, 2012), as well as its appropriateness when using a smaller sample size. The PLS path model was evaluated in the following steps:

- Evaluation of the measurement model (outer model) with regards to the reliability and validity of variables.
- Evaluation of the structural (inner model) with respect to the variance accounted for (AVE), direct relationships (path estimates), and the predictive relevance of the structural model.

3.1 Conceptual Framework and Hypothesis

The conceptual framework for this study was drawn from reviewing maintenance and quality literature. In this study, machine maintenance types represent the exogenous variables while quality of output is the endogenous variable. The framework for this study proposes that there is a direct relationship or link between machine maintenance type (breakdown maintenance, preventive maintenance, corrective maintenance, and predictive maintenance) and quality of output.

The path model was drawn from the conceptual framework developed in *figure 2* below.

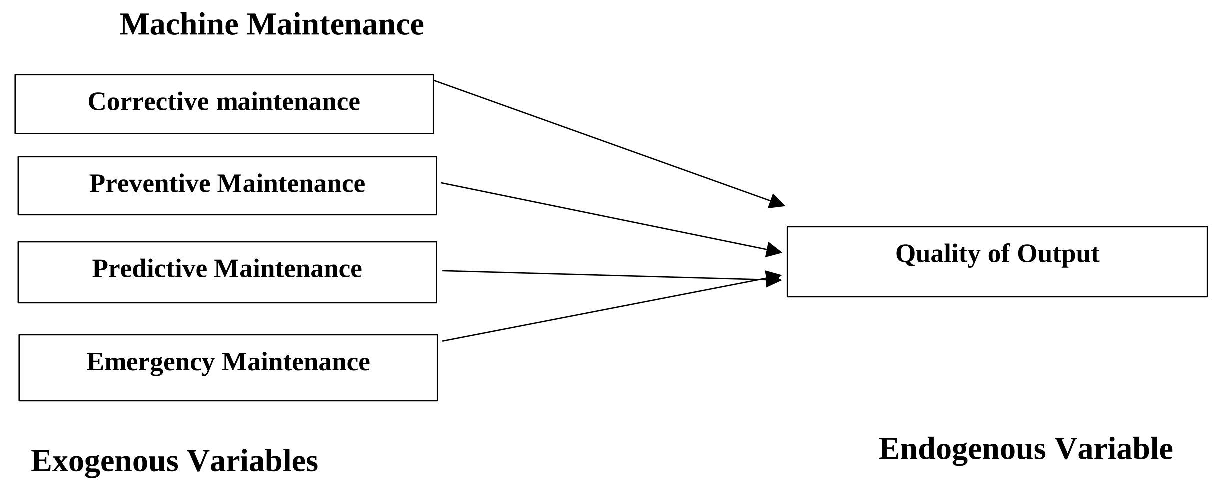

Figure 2: Conceptual Framework ***{Source:*** *Authors' Own Construction}*

4. RESULTS

The Composite Reliability (CR) scores, Cronbach's alpha, and Average Variance Extractor (AVE) were used to determine the indicator reliabilities, internal consistency, and convergent validity of measured constructs. *Table 1* below shows the results.

Table 1: Individual Item Reliability and Construct Validity

Maintenance Types	Factors	Description	Loading	AVE	CR	Cronbach Alpha
Breakdown Maintenance	BDown	Machine Downtime	**0.702**	**0.555**	**0.714**	**0.739**
	BSAvail	Sustained Availability	0.533			
	BEff	Machine Efficiency	0.653			
	BVal	Value addition	0.419			
	BScrap	Scrap/defective products	**0.735**			
Corrective Maintenance	Cdown	Machine Downtime	0.290	**0.545**	**0.705**	**0.716**
	CSAvail	Sustained Availability	**0.701**			
	CEff	Machine Efficiency	0.235			
	CVal	Value addition	**0.765**			
	CScrap	Scrap/ defective products	-0.821			
Preventive Maintenance	PvDown	Machine Downtime	0.290	**0.646**	**0.784**	**0.752**
	PvAvail	Sustained Availability	**0.899**			
	PvEff	Machine Efficiency	**0.760**			
	PvVal	Value addition	-0.247			
	PvScrap	Scrap/ defective products	0.521			
Predictive Maintenance	PrDown	Machine Downtime	**0.730**	**0.694**	**0.819**	**0.774**
	PrAvail	Sustained Availability	**0.718**			
	PrEff	Machine Efficiency	0.366			
	PvVal	Value addition	0.557			
	PvScrap	Scrap/ defective products	0.453			
Quality Output	ConRel	Conformance	**0.749**	**0.593**	**0.811**	**0. 799**
	Reliab	Reliability	**0.753**			
	Durab	Durability	0.398			
	Price	Price	-0.594			
	Charact	Characteristics	**0.842**			

Table 1 above shows that the AVEs, CR, and Cronbach's alphas all exceeded the threshold values of 0.5, 0.7, and 0.7 respectively. This implies that the measurement model is considered satisfactory with evidence of internal reliability and convergent validity. However, after running the PLS algorithm for the first time, indicators that loaded weakly below the 0.70 cut-off point were deleted and the model was run again. *Figure 3* below shows the results after the weakly loaded indicators were deleted.

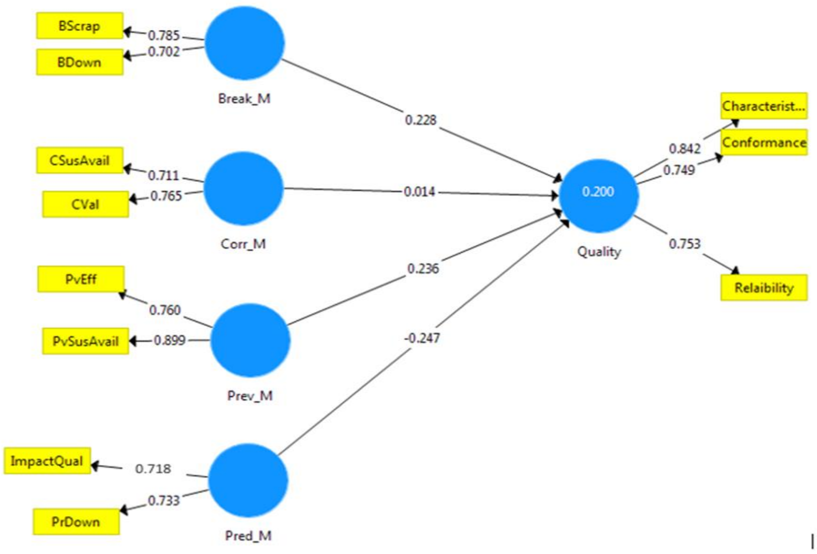

Figure 3: Result of PLS indicator outer loadings

4.1 Discriminant Validity

Discriminant validity refers to the extent to which a given variable is different from other variables. This was evaluated using Heterotrait-Monotrait (HTMT) threshold of <0.85 0r 0.9.

Table 2: Heterotrait-Monotrait (HTMT) Ratio

	Break_M_	Corr_M	Pred_M	Prev_M	Quality
Break_M_					
Corr_M	**0.69**				
Pred_M	**0.430**	**0.417**			
Prev_M	**0.180**	**0.366**	**0.344**		
Quality	**0.730**	**0.261**	**0.632**	**0.425**	

As indicated in *table 2* above, HTMT values did not exceed the 0.9 threshold which shows that measures of constructs, in the model, that are not supposed to be related were indeed found to be unrelated (distinct) of each other.

4.2 Assessment of Structural Model

Significance and relevance of structural relationships, Goodness of fit and test for multicollinearity were used to assess structural model. The model passed the test for multicollinearity. All Variance Inflation Factor (VIF) values are below the value of 5; indicating that there is no collinearity issues (see *table 6* in Appendix B). Therefore, a change in a particular latent variable under consideration does not affect the other.

4.2.1 Test for Direct Relationships

To find out the relationship between machine maintenance type and quality of output, bootstrapping technique was used to test the significance between variables (direct relationships and effects) using a two tailed t-distribution. The bootstrap was run using 5000 iterations at 0.05 significance level.

Table 3: Test for Significance of Hypothesis Using Bootstrapping

Dependent variable: Quality	Standardized beta	Standard error	T.Statistic	P.Value	Inference
Breakdown	0.245	0.086	2.639	**0.009**	**Significant**
Corrective	0.043	0.098	0.141	**0.888**	**Insignificant**
Predictive	-0.267	0.110	2.248	**0.025**	**Significant**
Preventive	0.239	0.100	2.368	**0.018**	**Significant**
R^2 =0.615 $\overline{R}^2$ =0.601					

Table 3 above shows that there is a significant relationship between all maintenance types and quality of output except for corrective maintenance which has an insignificant relationship with quality of output. This is because corrective maintenance is need-based, therefore requires less planning, lower short-term cost and reduced downtime which allows the maintenance

department to focus on other areas until needed. Hence, it's true effect on quality of output is not felt much.

R^2 (Coefficient of determination) was used to measure the overall effect of machine maintenance type on quality of output. The results indicate that 61.5% of the variation in the quality of output is determined by the variations in maintenance types (breakdown, corrective, preventive and predictive maintenance).

Figure 4 below further explains the relationships

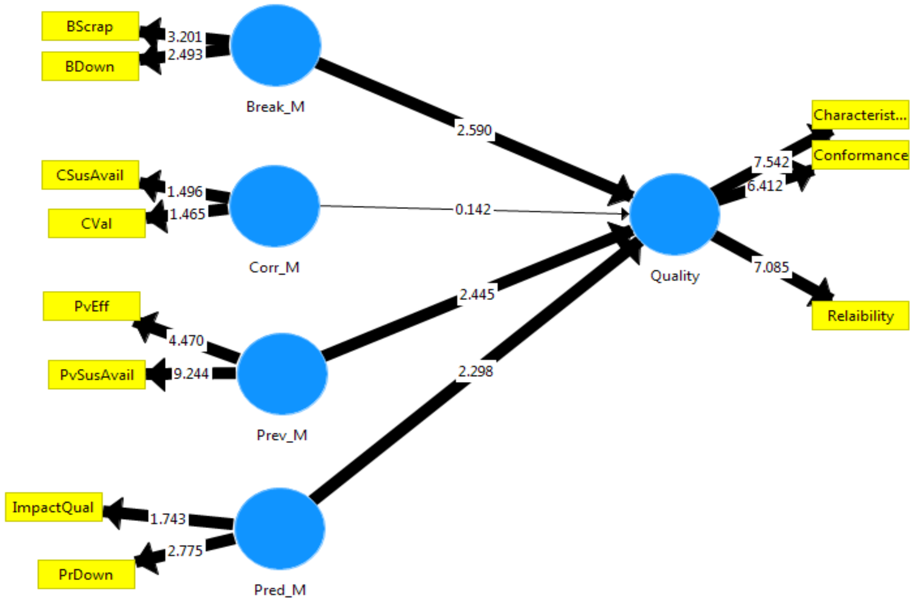

Figure 4: Result of PLS algorithm for direct relationships

4.3 Machine Maintenance as a Source of Reliability and Quality

Respondents were asked to rate the performance of machines as a result of maintenance with regards to sustained availability and reliability, value addition (increased meantime to failure, cost), the efficiency of machines, and rate of machine breakdown. The findings indicate that majority of respondents, 66.7%, rated sustained availability and reliability of machines after machine maintenance as high, while 0.8% rated it as very low. Majority (43.3%) of respondents indicated that they observed some value added to machines after performing machine maintenance. Findings further revealed that 45% of the respondent's representing majority indicated that after maintenance, the reduction of overall plant operation cost was average whiles 2.5% of respondents rated it low. Results also show that majority (44.2%) of the respondents rated the efficiency of machines after machine maintenance as very high. Majority, 40% of the respondents indicated that the rate of machine breakdown after machine maintenance was average whiles 1.7% of respondents indicated very high.

Table 4: Maintenance as a source of Reliability and Quality

Indicator	5	4	3	2	1	Mean	Std. Dev.
Sustained availability and reliability of machines	22.5%	66.67%	3.3%	6.7%	0.8%	24	29.4
Value addition (less machine breakdowns, low production cost)	29.2%	26.7%	43.3%	0.8%	0.0%	30	18.9
Overall plant operation cost reduction	20%	32.5%	45%	2.5%	0.0%	30	18.9
Efficiency of the machines production	44.2%	41.7%	10.8%	2.5%	0.8%	24	22.9
Rate of machine breakdown	1.7%	4.2%	40%	27.5%	26.7%	18	17.7
Average						**26**	**21**

Respondents were further asked to rate the contribution of machine maintenance to the quality of products, all things being equal. The results show that majority, 40.8% of respondents indicated that machine maintenance contributed averagely to quality whereas 1.7% rated the contribution of machine maintenance to quality low. Results are shown below in *table 5.*

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Table 5: The contribution of Machine Maintenance to the Quality of Products

Rating	Frequency	Percent	Cumulative Percent
Very Low	2	1.7	1.7
Low	9	7.5	9.2
Average	49	40.8	50.0
High	44	36.7	86.7
Very High	16	13.3	100.0
Total	**120.0**	**100.0**	

On whether the adoption of a particular maintenance type positive or negatively affects the quality of products (conformance to specification), 90% of the respondents agreed whiles 10% of respondents disagreed. Upon further interaction with respondents, it was realized that breakdown maintenance contributed negatively to the quality of output whereas preventive maintenance contributed positively to quality output.

5. CONCLUSION AND IMPLICATIONS

The study sought to examine the relationship between machine maintenance type and quality of output as well to establish whether machine maintenance contributes to quality of output among Ghanaian manufacturing firms. The relationship between corrective maintenance and quality of output was found to be insignificant. This implies that corrective maintenance type has very little influence on the quality of output. Although literature, particularly linking corrective maintenance to quality of output is very rare, it has been argued that adopting corrective maintenance can increase machine availability which guarantees an improvement in machine productivity and efficiency if done properly (Ribeiro, 2011). There is, therefore, the need to conduct more research to find out the real effect of corrective maintenance on the quality of output. In this sense, maintenance or operations managers should make a point to document real causes of quality deficiencies in their departments. Also, the maintenance type(s) adopted by firms significantly affects the quality of output. Machine maintenance if properly and effectively done can be a source of machine reliability, availability, efficiency, and ensure the quality of output.

Nonetheless, the study proved that a strong and significant relationship between the other maintenance types in the study and the quality of output. This finding is consistent with the findings of Ollila and Malmipuro (1999), which revealed that machine maintenance type is among the three most important reasons why there are quality problems in manufacturing firms. Similarly, the finding of this study agrees with the findings of Chiekezie, Nzewi and Odeki (2017), which revealed that a positive relationship exists between machine maintenance types and quality of output. This is to say that, if a company minimizes breakdown maintenance, quality defects are also minimized and vice versa. Similarly, the more preventive maintenance is adopted, the less product defect (high quality output) can be assured. The findings also, confirms the observation by Ben-Daya and Dufua (1995), who identified that there were indeed explicit links between the machine maintenance type a firm adopts and the quality of output. The finding further agrees with the findings of Ribeiro (2011), who states that preventive maintenance is positively related to cost reduction and quality of output. Thus, unplanned maintenance types should be minimized by adopting other enhanced or planned maintenance methods such as preventive maintenance and predictive, reliability-centered, and condition-based maintenance.

The findings imply that machine maintenance affects the quality of output either positively or negatively and should be considered as a potential source of quality problems. In Ghana, managers have, over the years seen machine maintenance as a cost to their firms and have not taken advantage of the potential of a well performing machine maintenance practice. This study showing that machine maintenance and the type adopted by a firm is directly related to the quality of output can be a way to encourage maintenance, operations, and quality managers to consider machine maintenance as a source of quality improvement rather than just cost. This is to confirm the assertion that a well-functioning machine is a prerequisite to product quality as observed by Ollila and Malmipuro (1999).

APPENDICES

Appendix A

1. Survey Questionnaire

The purpose of this questionnaire is to gather information to help determine the relationship between machine maintenance type and quality of output in Ghanaian Manufacturing companies. Your contribution is very essential to completing our research. We will be very grateful if you could spare a few minutes of your time to complete this questionnaire. All responses will be treated with utmost confidentiality and will be used for academic purpose only.
Thank you.

***Section A*: General Information**
Please answer by ticking [√] below as appropriate
1. What is your highest level of education?
a) High school [ ]
b) Diploma [ ]
c) Undergraduate [ ]
d) Postgraduate [ ]
2. How many years have you worked in your current position?
a) Less than 2 years [ ]
b) 2- 5 years [ ]
c) 5 - 10 years [ ]
d) Above 10 years [ ]

***Section B*: Maintenance Department**
1. Kindly tick (√) appropriately, the machine maintenance approach adopted by your company.

Maintenance Approach	
Planned (Proactive) Maintenance [Activities that plan, record and control work to keep machines at acceptable maintenance levels].	
Unplanned (Reactive) Maintenance	

[Repair, replacement or restoring a machine to its minimum acceptable condition after the occurrence of failure].	

2a. Kindly tick (√) appropriately, the specific type(s) of machine maintenance adopted by your company.

I	**Unplanned Maintenance**	Breakdown (emergency) Maintenance	
		Corrective Maintenance	
II	**Planned Maintenance**	Predictive Maintenance (Based on the analysis of some physical observations e.g. change of oil colour, change in vibrations and the change in noise levels)	
		Preventive Maintenance (e.g. shutdown maintenance)	
		Reliability Centered Maintenance	
		Condition Based Maintenance	
		Scheduled Maintenance	

2b. Please specify any other maintenance type adopted by the company but not mentioned above ………………………………………………………………………
……

3. Using a score out of 5: (**5** being 'Very High', 4 'High', 3: 'Average', 2:'Low' 1:'Very Low'), tick (√) appropriately how you would rate the extent of the application of the machine maintenance practices that you selected in question 2 above.

Maintenance Practices	**Response**				
Breakdown (emergency) Maintenance (Repair of Breakdown)					
Corrective Maintenance					
Predictive Maintenance (Based on the analysis of some physical observations e.g. change of oil colour, change in vibrations and the change in noise levels)					
Preventive Maintenance (e.g. shutdown maintenance)					
Reliability Centered Maintenance					
Condition Based Maintenance					

4. From question 2 above, is there a particular machine maintenance practice which can be regarded as the best compared to the others? Please state below
………………………………………………

***Section C*: Operations Department**
1. In a score out of 5**:** (**5** being 'Very High', **4** 'High', **3** 'Average', **2** 'Low' **1** 'Very Low'), tick (√) appropriately how you would rate the performance level of machines based on the adoption of the following machine maintenance types. Base your judgment on the indicators given.

Maintenance Type		**5**	**4**	**3**	**2**	**1**
Breakdown/Emergency	**Machine breakdown time**					
	Value Addition					
	Machine efficiency					
	Sustained availability					
	Scrap/defects					
Preventive	Value Addition					
	Machine efficiency					
	Sustained availability					
	Scrap/defects					
Corrective	Value Addition					
	Machine efficiency					
	Sustained availability					
	Scrap/defects					
Predictive	Value Addition					
	Machine efficiency					
	Sustained availability					
	Scrap/defects					

2. Do particular maintenance type(s) adopted at a particular point in time by the company affect the quality of products?
Yes [ ] No [ ]

3. In a score out of 5: (5 being 'Very High', 4 'High', 3: 'Average', 2:'Low' 1:'Very Low'), tick appropriately (√), how you would rate the level of **quality of output** as a result of the maintenance type(s) adopted by your company. (Please be guided by your answer to question 1 above)

S/N		**Maintenance Type**	**5**	**4**	**3**	**2**	**1**
I	**Unplanned Maintenance**	Breakdown/Emergency					
		Corrective					
II	**Planned Maintenance**	Predictive					
		Preventive					
		Reliability Centered					
		Condition Based					
		Scheduled					

***Section D*: Quality Department**

1. How would you rate the number of customer complaints you have received in the last 2 years. Very High [ ] High [ ] Average [ ] Low [ ] Very Low [ ]

2. Below are some dimensions of quality. In a score out of 5**:** (**5** being 'Very High', 4: 'High', 3: 'Average', 2:'Low' 1:'Very Low'), tick (√) appropriately **how you would rate the following with respect to customer complaints.**

Customer Complaints	**5**	**4**	**3**	**2**	**1**
Reliability (Delayed delivery)					
Conformance (Defects/variability in product quality)					
Durability (Storage and shelf life)					
Features (Packaging, labelling, manuals)					
Primary product characteristics/performance (Texture, size, appearance, acidity, sweetness etc.)					
Price (Too high)					

3. To what extent do you agree that the complaints mentioned in question 12 above can be attributed/ linked to poor machine maintenance?
Strongly Agree [ ] Agree [ ]
Neutral [ ] Disagree [ ] Strongly Disagree [ ]

APPENDIX B

Test for Multicollinearity

Variance Inflation Factor (VIF) was analyzed to assess multicollinearity among the independent variables. A threshold of 5 or lower is needed to avoid collinearity issues (Hair et al., 2011). From *table 6* below, all VIF values are below the value of 5; indicating that there are no collinearity issues. Therefore, a change in a particular latent variable under consideration does not affect the other.

Table 6: Multicollinearity Assessment

	VIF
BDown	**1.012**
BScrap	**1.012**
CSusAvail	**1.008**
CVal	**1.008**
Characteristics	**1.439**
Conformance	**1.325**
PrVal	**1.098**
PrDown	**1.098**
PvEff	**1.188**
PvSusAvail	**1.188**
Relaibility	**1.277**

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Competing Interest

The authors declare that they have no competing interest.

Authors' Contribution

Benjamin Osei Gyamfi: Writing - Reviewing and Editing, Methodology, Data Curation, Software, Formal analysis, Visualization, Supervision, Resources.

Gloria Zigah: Conceptualization, Writing - Original draft preparation, investigation, project administration, Visualization, Validation, Resources.

REFERENCES

[1] Abor, J., Quartey, P. (2010). Issues in SME Development in Ghana and South Africa. International Research Journal of Finance and Economics, 39(6), 215-228.

[2] Adjaye, R.E. (1994). Design and Optimized Operation with Reliability Centered Maintenance. IEE Conference on Electrical Safety in Hazardous Environment, 399, 165-71

[3] Ahuja, I.P.S., & Khamba, J.S. (2008). Total Productive Maintenance: Literature Review and Directions. International Journal of Quality & Reliability Management, 25 (7), 709 – 756.

[4] Al-Najjar, B. (1996). Total quality maintenance: an approach for continuous reduction in cost of quality products. Journal of Quality in Maintenance Engineering, 2 (3), 4-20.

[5] Al-Najjar, B. (2000). Accuracy, Effectiveness and Improvement of Vibration-Based Maintenance in Paper Mills: A Case Study. Journal of Sound and Vibration, 229 (2), 389-410.

[6] Al-Najjar, B. (2007). The Lack of Maintenance and Not Maintenance Which Costs: A Model to Describe and Quantify the Impact Of Vibration-Based Maintenance on Company's Business. International Journal of Production Economics, 107 (1), 260–273.

[7] Al-Najjar, B., & Alsyouf, I. (2004). Enhancing A Company's Profitability and Competitiveness Using Integrated Vibration-Based Maintenance: A Case Study. European Journal of Operational Research 157, 643–657.

[8] Alsyouf, I. (2004). Cost effective maintenance for competitive advantages. Doctoral dissertation, Vaxjo University, Sweden.

[9] Alsyouf, I. (2007). The Role of Maintenance in Improving Companies' Productivity and Profitability. International Journal of Production Economics, 105 (1), 70-8.

[10] Al-Turki, U. (2011). Methodology and Theory: A Framework for Strategic Planning In Maintenance. Journal of Quality in Maintenance Engineering, 17(2), 150-162.

[11] Aziz, N., & Khalid, P., (2014). Utilizing TPM Functionalities on Remote Server. International Conference on Advances in Computing and Information, 93-96.

[12] Bagshaw, K. B., (2017). A Review and Analysis of Plant Maintenance and Replacement Strategies of Manufacturing Firms in Nigeria. African Journal of Business Management, 11(2), 17-26.

[13] Ben-Daya, M., & Duffuaa, S.O., (1995). Maintenance and quality: the missing link, Journal of Quality in Maintenance Engineering, 1 (1), 20-6.

[14] Joseph Acquah, Yusif Arthur, Damianus Kofi Owusu (2020), Analysis of the Relationship between Credit Risk and Bank Performance of Some Commercial Banks in Ghana. IJBMR 8(2), 34-51. DOI: 1037391/IJBMR.080202.https://ijbmr.forexjournal.co.in/archive/volume-8/ijbmr-080202.html

[15] Carter, R.A., (2001). Shovel Maintenance Gains from Improved Designs, Tools and Techniques. Engineering and Mining Journal, 202 (8), 7.

[16] Chiekezie, O. M., Nzewi, D. H. N., & Odekina, F. (2017). Maintenance Culture and Performance of Selected Manufacturing Firms in Benue State, Nigeria. Archives of Business Research, 5(3).

[17] Crosby, P., (1979). Quality Is Free: The Art of Making Quality Certain. McGraw-Hill, New York.

[18] Defoe, J.A., & Juran, J.M., (2010). Juran's Quality Handbook: The Complete Guide to Performance Excellence. 5th ed., McGraw Hill, New York.

[19] Deming, W.E. (1995). Out of the Crisis, 7th ed., MIT Center for Advanced Engineering, Cambridge, MA.

[20] Dilworth, J.B. (1992). Operations Management: Design, Planning and Control for Manufacturing and Services. McGraw-Hill, New York.

[21] Eliyahu M. G., (1984). THE GOAL: A process of ongoing improvement. 1st Ed., North River Press, MA, United States.

[22] Feigenbuam, A.V. (1991). Total Quality Control. 3rd Ed., McGraw-Hill, New York.

[23] Fenny, A.P. (2017). Ghana's Path to an Industrial Led Growth: The Role of Decentralisation Policies. International Journal of Economics and Finance, 9(11), 22-34.

[24] Ghana Statistical Service, (2015). Integrated Business Establishment Survey report, 2015. Available at http://www.statsghana.gov.gh/databases/ibes.html. [Accessed 27/09/19].

[25] Goetsch, D. L., & Davis S., (2010). Quality Management for Organization Excellence: Introduction to Total Quality. 7th Ed., Pearson Education Limited, Edinburgh.

[26] Gopalakrishnan P., & Banerji A.K., (2004). Maintenance and spare parts management. Prentice Hall, New Delhi.

[27] Hair, J., Black, W., Babin, B.Y.A., Anderson, R., & Tatham, R. (2010). Multivariate Data Analysis. A Global Perspective, Pearson Prentice Hall, Upper Saddle River, NJ.

[28] Hair, J. F., Ringle, C. M., & Sarstedt, M. (2011). PLS-SEM: Indeed a silver bullet. Journal of Marketing theory and Practice, 19(2), 139-152.

[29] Ishikawa, K. (1990). Introduction to Quality Control. Chapman & Hall, London.

[30] Juran, J.M. (1992). Quality by Design: The New Steps for Planning Quality into Goods and Services, Free Press. Macmillan, Inc., New York.

[31] Kamau, J.M., (2014). Maintenance Management Practices and Operational Performance in Electricity Production Stations in Kenya. Unpublished Theses. University of Nairobi, Kenya.

[32] Karande, P., & Chakraborty, S. (2013). Material handling equipment selection using weighted utility additive theory. Journal of Industrial Engineering 6(2), 123-32

[33] Dr. Sada H. Jaman, Dr. Kevin C. James and Dr. Desire S. Luamba (2022), Impacts of Employee Engagement and Workforce Productivity on Retail Companies. IJBMR 10(1), 6-18. DOI: 10.37391/IJBMR.100102.

[34] Kirkwood C.K., Mech B.E. (2006) Optimising Maintenance Performance: An Application of the Theory of Constraints. In: Mathew J., Kennedy J., Ma L., Tan A., Anderson D. (eds) Engineering Asset Management. Springer, London.

[35] Kumar, A., Motwani, J., Douglas, C., & Das, N. (1999). A quality competitiveness index for Benchmarking. An International Journal, 6 (1), 12-21.

[36] Kutucuoglu, K.Y., Hamali, J., Irani, Z., & Sharp, J.M., (2001). A framework for managing maintenance using performance measurement systems. International Journal of Operations & Production Management, 21(1/2), 173-194.

[37] Maggard, B. N., & Rhyne, D.M. (1992). Total productive maintenance: A timely integration of production and maintenance. Production and Inventory Management Journal, 33 (4), 6-10.

[38] Mitchell, E., Robson, A. and Prabhu, V. (2002), The impact of maintenance practices on operational and business performance. Managerial Auditing Journal, 17 (5), 234-240

[39] Miyake, D.I. and Enkawa, T. (1999). Matching the promotion of total quality control and total productive maintenance: an emerging pattern for nurturing of well-balanced manufactures. Total Quality Management & Business Excellence, 10 (2), 243-69.

[40] Mobley R. K. (2004). Maintenance Fundamentals. 2nd Ed., Elsevier Butterworth-Heinemann, USA.

[41] Mobley, R. K., (2008). Introduction to the Theory and Practice of Maintenance: Maintenance Engineering Handbook, 7th Ed., McGraw Hill Companies Inc., USA, p. 35-42.

[42] Monecke, A. & Leisch, F. (2012). semPLS: structural equation modeling using partial least squares. Journal of Statistical Software, 48 (3), 1-32

[43] Murthy, D., Atrens, A. & Eccleston, J. (2005). Strategic Maintenance Management. Journal of Quality in Maintenance Engineering, 8 (4), 287-305.

[44] Ollila, A. and Malmipuro, M., (1999). Maintenance has a role in quality. The TQM Magazine, 11 (1), 17-21.

[45] Osei Mensah, J., Copuroglu, G., & Appiah Fening, F., (2012). The status of Total Quality Management (TQM) in Ghana, International Journal of Quality & Reliability Management, 29 (8), 851-871.

[46] Pannerrselvam, R., (2009). Production and Operations Management. 2nd ed., PHI Learning Private.

[47] Parsons, T., (1977). Social Systems and the Evolution of Action Theory. New York: Free Press, 23, (5), 429.

[48] Raut, S., & Raut, N., (2017). Implementation of TPM to Enhance OEE in A Medium Scale Industry, International Research Journal of Engineering and Technology (IRJET). 2395 -0056 04 (5).

[49] Ribeiro, J., (2011). Status of Production Equipment SMPS Performance Maintenance Engineering in the Ghanaian Manufacturing Industry. [Unpublished Thesis]. Kwame Nkrumah University of Science and Technology, Kumasi.

[50] Roup, J. (1999). Moving beyond TPM to total plant reliability: redefining the concept to optimize benefits. Plant Engineering, 53 (2), 32-37.

[51] Saunders, M., Lewis P., & Thornhill, A. (2007). Research Methods for Business Students. 5th Ed., Prentice Hall, New Jersey.

[52] Slater, G., & Spencer, D.A., (2000). The Uncertain Foundations of Transaction Costs Economics. Journal of Economic Issues, Taylor & Francis Journals, 34(1), 61-87.

[53] Swanson, L., (2001). Linking maintenance strategies to performance. International Journal of Production Economics, 70, 237–244.

[54] Telang A. D. & Telang A., (2010). Comprehensive Maintenance Management: Policies, strategies and Options. PHI learning Private Limited, New Dehli, India.

[55] Veldman, J., Wortmann, H., & Klingenberg W., (2011). Methodology and Theory: Typology of condition based maintenance. Journal of Quality in Maintenance Engineering, 17(2), 183- 202.

[56] Visser, J.K., (1998). Maintenance management: An appraisal of current strategies. ICOMS 98, Paper 031. Available at www.emeraldinsight.com/1355-2511.htm [Accessed 19/01/20]

[57] Waeyenbergh, G., & Pintelon, L., (2002), A framework for maintenance concept development. International Journal of Production Economics, 77 (3), 299-313.

[58] Weber, A., (1909). Theory of industrial location, CSISS Classics.

[59] Wild, R., (2002). Operations Management. 6th Ed., 11 York Road, London.

[60] Zhou, X., Xi, L. & Lee, J. (2006), A Dynamic Opportunistic Maintenance Policy for Continuously Monitored Systems. Journal of Quality in Maintenance12 (3).