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Maintenance Management and Organizational Performance in Selected Manufacturing Firms, Akwa Ibom State

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ABSTRACT: *This research was designed to examine the relationship between Maintenance Management and organizational performance among selected manufacturing firms in Akwa Ibom State. Survey research design was adopted for the study and a sample size of 258 respondents was drawn from the population of 275. For the objective of the study to be achieved, five hypotheses were formulated. The major instrument for data collection was a structured questionnaire administered to the respondent using random sampling techniques. Data collected were analysed using simple percentage and Ordinal Logistic Regression. Results show that there is a significant correlation between variables of maintenance management such as corrective, preventive, condition-based maintenance and pre-determined maintenance and organizational performance variables of effectiveness, efficiency and profitability among selected manufacturing firms in Akwa Ibom State. Based on the finding of the analysis, management has to provide the maintenance teams with a maintenance management software in order to ensure proper interventions monitoring as well as smooth communication between technicians and other professionals to enhances business success. Consequently, it is recommended that Management should ensure that Corrective maintenance is implemented right after a defect has been detected on a piece of equipment or a production line: its objective is to make the piece of equipment work normally again, so that it can perform its assigned function. Corrective maintenance can either be planned or unplanned depending on whether or not a maintenance plan has been created.*
KEYWORDS: maintenance management, maintenance culture, organizational performance

INTRODUCTION

In the last few decades, manufacturing organizations were forced to shift their business models from closed system-orientations, to more open system-orientations. This shift was

brought about by drastic competitive forces, which made the target market the focus of organizational, operational and strategic practices. Today's manufacturing organizations are required to operate as open operational systems. In such systems, advanced operational manufacturing technologies are blended with modern information and communication technologies to integrate and coordinate operational resources, processes, and activities in order to generate a stream of value-added operations aimed at capturing and sustaining a competitive advantage. With the increasing complexity, scope, and organizational role of operational advanced manufacturing technologies, the maintenance of these technologies is becoming very critical to the ability of the organization to compete. In this context, operations management, especially maintenance management, is taking on a broader organizational strategic role.

Traditionally, maintenance, with its multifaceted activities, resources, measurement, and management, has been important to manufacturing organizations. However, in recent years, the need to manage the different facets of maintenance more effectively has gained added importance due to changing operational technologies, and the changing organizational role of maintenance. Markets are affected by diverse customer needs, which demand higher quality, shorter delivery time, higher customer service level and lower prices. At the same time, product life cycles are becoming shorter and shorter. Success in any competitive context depends on having either a cost advantage or a value advantage, or, ideally, both and the survival of any business depends on its ability to compete effectively (Madu, 2011). Therefore, the manufacturing company structure has changed from a labour intensive industry to a technology-intensive, i.e. capital intensive, industry.

Management system is a set of interconnect processes that brings to the organization increased efficiency and effectiveness in achieving determined objectives. Process is defined as a set of activities using resources and regulations to enable the transformation of inputs into outputs. The process approach represents identification, interaction and process control in such way that the output of one process is presented as input to the next process. This relation can be understood as the certain interconnection of process (Nenadal. 2008 and Popovic 2010). Continual improvement of the organization's performance needs to be taken as a major goal of any kind of organization (Maintenance terminology EN 13306, 2001) understands maintenance as a process which includes management, administrative and technical activities in order to maintain or restore equipment into the required state. maintenance is defined as the mishmash of all technological and management actions, including administration action, planned to engaged an item in, or restore it to a state in which it can perform a required function (Waeyenbergh and Pintelon, 2014).

Maintenance impact on business performance aspects such as productivity and profitability has increased. A day's output lost because of an unplanned stoppage will never be recovered without additional costs being incurred, e.g. overtime working. The importance of the maintenance function has increased, due to its role in keeping and improving availability, performance efficiency, quality products, on-time deliveries, environment and safety requirements, and total plant cost effectiveness at high levels.

Effective maintenance management has been stressed by literature for several reasons. Firstly, maintenance management is stressed due to the rising cost of maintenance in relation to operational costs (Garg and Deshmukh 2006). Secondly, due to the important role it plays in the facilities management (Meng 2011; Mangano and Marco 2014). Lastly, effective maintenance management is sought after due it its direct effect on the safety concerns in health-care organizations (Shohet, LavyLeibovich, and Bar-On 2013; Lavy and Shohet 2009).

Despite the efforts of many organizations to align their production and maintenance strategies, it appears that the measurement of maintenance performance still faces a lack of understanding. This gap has led to an under appreciation of the real value of the maintenance function for the organizational competitiveness (Berges, Galar, and Stenström 2013). Based on an extensive literature review, three relevant themes related to maintenance performance measures, measurement, and management emerged (Simões, Gomes, and Yasin 2011). These themes include effective utilization of maintenance resources, total maintenance and information systems support, measurement, measures, and human factor management. These themes clearly incorporate the critical aspects of an effective maintenance system.

Based on a more recent literature review, it seems that not much progress has been made regarding the process of actually designing and implementing a practical maintenance performance measurement framework (Parida. 2015). This leaves maintenance managers with many questions and few answers when it comes to adopting practical maintenance measures and measurement processes. As such, maintenance performance measures and measurement process continue to pose a serious practical challenge to managers (Parida et al. 2015).This study therefore intends to analyze the relationship among maintenance management and organizational productivity. The study will examine maintenance management processes within the workplace to further understand the relationship between it and organizational performance in selected manufacturing industries in Southern Nigeria

Statement of the Problem

The rate at which business in the manufacturing sectors have been closed down is almost as high as the rate of new entrants. Careful looks have pointed to the direction of maintenance culture among managers and other organizational stakeholders. Maintenance culture such as preventive, corrective, pre-determined and condition-base-maintenance approaches which comprise of provision of adequate care of the hard-earned infrastructure have not gained ground in the consciousness of resource managers in the manufacturing firm over the years. This condition has resulted in abandoned factory plants, dilapidated buildings, deserted vehicles with minor problems, moribund industries and a host of other properties which have little or insignificant problems. The ugly consequence is economic stagnation, poor quality, huge operating cost to this firms and subsequent collapse which aggregate to national economy.

Marquez and Gupta (2005), features the difficulty in Maintenance Management to lack of Maintenance Management models that could improve the understanding of the underlying dimensions of Maintenance. Visser (1998) further argues that, a body of knowledge is

lacking to clearly guide maintenance management. This led to difficulty in decisions making as to which maintenance delivery strategy to adopt (Marquez and Gupta, 2005). However, there is insufficiency of information on maintenance activities being undertaken within the industry. Adejuyigbe, (2006) reports that there are some levels of maintenance activities taking place within manufacturing industries but offer no specific details; for example the type of maintenance strategy adopted, equipment and technology employed, the role of the maintenance manager, training, documentation and influence on performance among others. To this end, this study therefore seeks to examine the extent to which maintenance management influences organizational performance.

Objectives of the Study

The broad objective of the study is to ascertain the relationship between maintenance management and organizational performance in selected manufacturing firms in Akwa Ibom State. The specific objective is to;

i. Examine the relationship between corrective maintenance and organizational effectiveness in manufacturing firms.
ii. Ascertain the influence of preventive maintenance on organizational efficiency in manufacturing firms.
iii. Examine the contribution of conditions based maintenance on organizational profitability in manufacturing firms.
iv. Examine the relationship between corrective, preventive, condition-based and Predetermined maintenance and organizational performance in manufacturing firms.
v. Examine the relationship between organizational culture, maintenance management and organizational performance.

Hypotheses of the Studies

H_{01}: There is no significant relationship between corrective maintenance and organizational effectiveness in manufacturing firms.
H_{02}: There is no significant relationship between preventive maintenance and organizational efficiency in manufacturing firms.
H_{03}: There is no significant relationship between condition-based and organizational profitability in selected manufacturing firms.
H_{04}: There is no significant relationship between corrective, preventive, condition-based and Predetermined maintenance and organizational performance in manufacturing firms.
H_{05}: There is no relationship between organizational culture, maintenance management and organizational performance.

LITERATURE REVIEW

Introduction

The review of literature was divided into the following sub-topics: conceptual framework under which we shall work at the concept of maintenance management, and concept of

organizational performance. We shall also look at theoretical framework and empirical review of study to give strong foundation to this work from these three horizons.

The Concept Maintenance Management

Maintenance has been defined by many authors in literature, those definitions has evolved in time, as during the last half-century, industrial maintenance has improved from a nonissue position in the company into a strategic concern. During this period, the role of maintenance within the organization has drastically been transformed. At first, maintenance was considered as failures that must be repairs, today it is an essential strategic element to achieve business objectives. (Pintelon and Parodi-Herz, 2008). Although literature review revealed many themes related to maintenance, (Simões, Gomes, and Yasin, 2011) notes that the area of maintenance performance and management is in need of more future systematic research efforts, also Smith (2002) specifies that literature lacks a clear definition of maintenance practices and then, readers are generally confused about the distinction between maintenance practices, actions and tasks. Such as maintenance is embedded in organizations; it has to respond to each requirement of stakeholders (management, operations, logistics, technology. etc.) which led to a complexity of maintenance tasks. (Pintelon and Parodi-Herz, 2008). As a consequence, maintenance has a relevant role for the industrial companies and then contribute to the growth of the industry sector in every country.

Maintenance is the combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to a state in which it can perform the required function (Rastegari and Salonen, 2013). It can be summarized as the repair and upkeep of existing equipment, buildings and facilities to keep them in a safe, effective as designed condition so that they can meet their intended purpose (Eti, Ogaji and Probert, 2004). The old concept of maintenance was that it is about preserving physical asset. The new concept is that it is about preserving the functions of assets" (Srivastava, 2004). Maintenance in its narrow meaning includes all activities related to maintaining a certain level of availability and reliability of the system and its components and its ability to perform a standard level of quality (Al-Turki, Yilbas, and Sahin 2014).

Marquez and Gupta (2006), defined maintenance management as the activities of management that determine maintenance objectives or priorities, strategies and responsibilities and implement them by means such maintenance planning, maintenance control and supervision and several improving methods including economical aspects in the organization. Marquez and Gupta (2006) go further to regard maintenance management as a process and also as a framework. As a framework, they noted that it is the essential supporting structure and the basic system needed to manage maintenance effectively.

Necessity of Maintenance Management:

Maintenance activities are related with repair, replacement and service of components or some identifiable group of components in a manufacturing plant so that it may continue to operate at a specified 'availability' for a specified period Smith, (2002). Thus maintenance management is associated with the direction and organisation of various resources so as to control the availability and performance of the industrial unit to some specified level

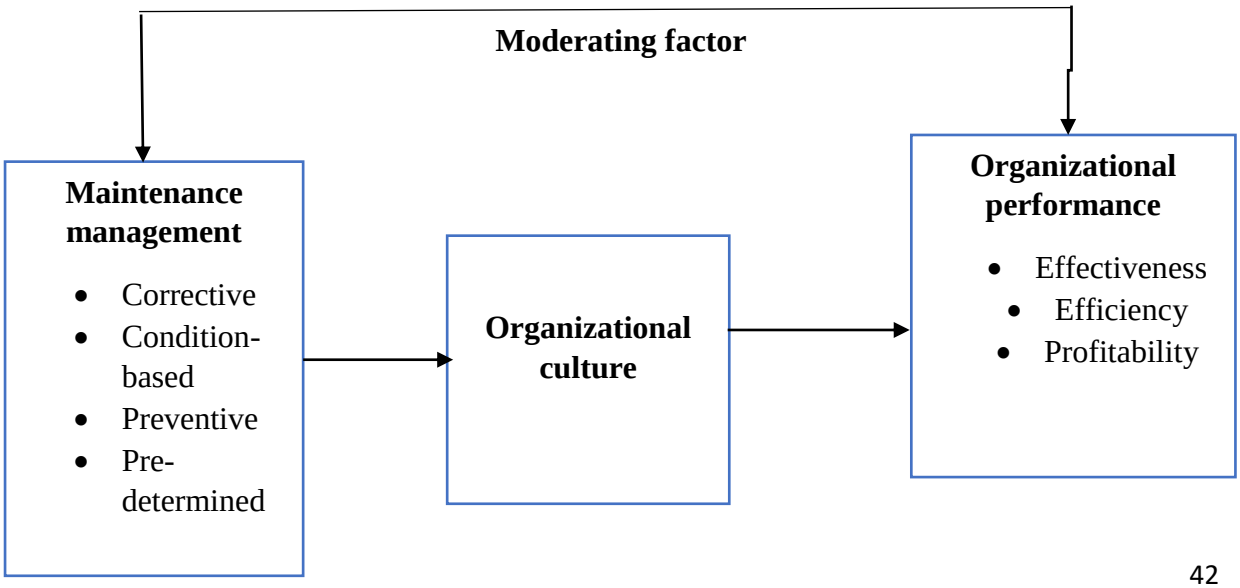
Veldman, (2011). Thus maintenance management may be treated as a restorative function of production management which is entrusted with the task of keeping equipment/machines and plant services ever available in proper operating condition. The minimization of machine breakdowns and down time has been the main objective of maintenance but the strategies adopted by maintenance management to achieve this aim have undergone great changes in the past. Maintenance has been considered just to repair the faulty equipment and put them back in order in minimum possible time.

In view of the utilization of mostly general purpose/conventional machines with low production output, the demands on maintenance function were not very high. The stringent control of dimensional tolerances and surface finish of the product have increased the tendency to adopt standardization and interchange-ability of parts/components of machines Al-Turki, (2011). In the current production setups even a minor down time leads to serious production problems both technological as well as economical Marquez and Gupta (2005). All this is due to tough competition in the industrial market. Under the present circumstances effective and objectively designed efforts to update maintenance management has become a necessity.

Absence of plant maintenance may lead to frequent machine breakdown and failure of certain productive centres/services which in turn would result in stoppages of production activities, idle man and machine time, dislocation of the subsequent operations, poor quality of production, failure to meet delivery dates of product supply, industrial accidents endangering the life of workers/ operators and allied costs etc.

Conceptual Framework

2.1.2.1 Figure 1. Model of maintenance management and organizational performance



Dimensions of Maintenance management

Corrective maintenance

Corrective maintenance is implemented right after a defect has been detected on a piece of equipment or a production line: its objective is to make the piece of equipment work normally again, so that it can perform its assigned function. Corrective maintenance can either be planned or unplanned depending on whether or not a maintenance plan has been created. Technicians apply unplanned corrective maintenance to react as soon as a failure couldn't be anticipated with preventive maintenance processes has been detected. Corrective maintenance gives technicians the possibility to perform their interventions without delay, even if they can choose whether they want to maintain the piece of equipment on the spot, right when a problem has been detected or later. Unplanned corrective maintenance can quickly become more costly than planned one because it can lead to costs which couldn't have been anticipated Veldman, (2011). Even if preventive maintenance doesn't always allow maintenance teams to anticipate each breakdown or failure as it remains very difficult to know exactly which components are about to fail, it still helps them reduce their scope of errors.

Condition-based Maintenance

This is the maintenance which is normally done when operating conditions deviate from the norm. It is done to detect emerging failures long before they occur Veldman (2011). It uses condition monitoring techniques to determine whether a problem exists in running equipment and for how long the equipment can operate before failure. This maintenance management practice detects and identify specific components in an equipment that are degrading, determine root cause of the problem and take remedial actions before failure of the equipment or operating asset (Tsang, 1999). Among all types of maintenance cited above, the condition-based maintenance is the most complicated to implement. It aims to prevent failures and requires regular check-ups of the state, the efficiency as well as other indicators of the system. All this data can be gathered automatically on the field or remotely thanks to a direct network connection to the equipment, in order to make sure that it is constantly controlled. Maintenance teams can decide whether they want to operate constant or regular interval control: they read counters, check parts' wear, control motors' temperature. These are all actions the teams can undertake to ensure that no piece will cause a breakdown that would damage the whole production line. Even if condition-based maintenance can seem difficult to implement, it is particularly economical. Since maintenance technicians proceed to very regular check ups of their parts and equipment, they will only take in charge the ones that need to be repaired or replaced. As a consequence, the purchasing department won't have to manage dozens of parts orders that will be stored and won't really be useful to ensure the proper functioning of the production line. In a nutshell, this type of maintenance allows companies to save money.

Preventive maintenance

Preventive maintenance is a planned or schedule maintenance that is done on the onset of failure to prevent or delay breakdowns and to minimize the impact of a breakdown (Wild, 2002). This maintenance management practice is based on the principle that prevention is better than cure. It consists of maintenance activities performed before equipment breaks down with the intent of keeping it operating acceptably to reduce likelihood of failure (Dilworth, 1992). The advantages of this practice are that it reduces rate of breakdowns, increases asset availability, maintain optimum efficiency of the equipment and reduces workload on maintenance staff. PM also increases productivity and safety of the workers (Murthy, 2005). Preventive maintenance is applied by technicians teams and managers before any breakdown or failure occurs. Its aim is to reduce the probability of breakdown or degradation of a piece of equipment, component or spare part. In order to implement such maintenance, teams have to take the part's history into consideration and keep track of the past failures. They are therefore able to identify the time ranges during which a piece of equipment might break down. This type of maintenance is described as planned because it's based on well-established maintenance programs and hard facts.

Predetermined maintenance

Predetermined maintenance, probably the less known one of all the maintenance types presented in this article, does not rely on the actual equipment's state but rather on the programs delivered by manufacturers. They elaborate these programs based on their knowledge of failure mechanisms as well as on Mean Time To Failure (MTTF) statistics which they observed on a piece of equipment and its various components in the past. Based on the assumption that this type of maintenance is only applied according to programs explained by manufacturers, failure risks are higher or lower whether the piece of equipment or part is new or old Veldman, (2011). Maintenance teams have no choice but to rely on these programs so they might not be able to anticipate failures (there's a risk for downtimes to occur and to have a direct consequence on productivity) and they also might proceed to completely useless parts replacement (which leads to additional costs that could have been avoided). This type of maintenance, just like others, is imperfect. It doesn't guarantee that a piece of equipment won't break down since all programs are based on failure statistics but they don't take the equipment's actual state into account.

The Concept of Organizational Performance

Organization performance has been the most important consideration for every organization, be it profit or non-profit organization. It has been very important for managers to know which factors influence an organization's performance in order for them to take full advantage and appropriate steps to initiate them. Organizational researchers among themselves have different opinions of performance as it continues to be a contentious issue. (Barney, 1997). According to Daft (2000), organizational performance is the organization's ability to attain its goals by using resources in an efficient and effective manner. Quite similar to Daft (2000), Richardo (2001) defined organizational performance as the ability of the organization to achieve its goals and objectives. According to Cascio (2014) organizational performance is the degree of attainment of work mission as measured in terms of work outcome, intangible

assets, customer link, and quality services. Kaplan and Norton (2001) defined organizational performance as the organization's capacity to accomplish its goals effectively and efficiently using available human and physical resources. This definition provides the justification for organizations to be guided by objective performance criteria when evaluating employees" work based performance. This is also helpful in evaluating the achievement of the organizational goals as well as when developing strategic plans for the organizations" future performance (Ittner & Larcker, 2012). Although many studies have found that different companies in different countries tend to emphasize on different objectives, literature suggests financial profitability and growth to be the most common measures of organizational performance. Conversely, researchers have argued that no one definition is inherently superior to another and the definition that a researcher adopts should be based on the disciplinary framework adopted for the study (Cameron & Whetten, 1983).

Dimensions of Performance

Profitability: Akintoye (2008) examined the effects of capital structure, financial flexibility, business risk and taxation on the performance of firms operating in Nigeria's food and beverage industry. Olutula and Obamuyi (2008) applied fixed effects model to 115 randomly selected small and medium enterprises (SMEs) in Ondo State, Nigeria. Size, interest rate and loans have significant positive association with profit but sales exerted an insignificant positive effect. On the other hand, age of firm exerted negatively on profit. In addition, Aburime (n.d.) examined the determinants of profits in Nigerian banking industry using a sample of 138 banks from 1980- 2007. The levels of competition as well as degree of foreign ownership have negative relationship with profitability. But using the First Bank of Nigeria Plc as a case study, Aremu, Ekpo and Mustapha (2013) revealed that credit risk, capital adequacy and cost efficiency were inversely related to firm performance while money supply and labour efficiency were directly associated with firm performance. They employed cointegration and error correction techniques.

Effectiveness: Maintenance management encompasses many operations and functions and can be described as the effective and efficient. Use of resources to make sure that the process and its facilities are kept to comply standards requirement assigned by the users (Usher, 2013). (Allen, 1993) defined maintenance management as a practical technique that is incomplete and uncoordinated, reflecting the range of contractors which are involved in maintenance works. The quality and efficiency of maintenance management operation depend on how information on the condition of the equipments, the needs of the users, and the works carried out is collected and used. In order to identify the effectiveness of maintenance management factors, key performance indicator is the best strategy to measure the performances of the equipment. Therefore, key performance indicators for each process are proposed to measure if requirements of each process are satisfied stated by (Cholasuke, 2004) this statement is in line with (Weber & Thomas, 2005) which affirmed that key performance indicator is a fundamental principle in maintenance management. As proposed by (Hazilah Abd. Manaf, 2005), routine monitoring and supervision is one of the key elements to assess and identify the performance of organization in implementing plans,

policies and procedures of maintenance management that relates to maintenance management.

Efficiency: Operational Efficiency represents the life-cycle cost-effective mix of preventive, predictive, and reliability-centered maintenance technologies, coupled with equipment calibration, tracking, and computerized maintenance management capabilities all targeting reliability, safety, occupant comfort, and system efficiency Nakajima (2018). One of the most important and critical matter of facility management is a field maintenance connected with continuous improving of manufacturing systems and its performance evaluation. As Rayes (2010) mention, to measure effectiveness of production equipment companies often use overall equipment effectiveness (OEE). OEE is one of the performance evaluation methods that are commonly used in the production industries.

Organizational Culture

Organizational culture, as a concept, has been studied in various different disciplines ranging from social anthropology to industrial organizational psychology (Schein, 2010) cited in Alshamari, (2017). Organizational culture can be defined by its aspects (Nahavandi and Malekzadeh 1993), dimensions (Yu 2004; Quinn and Cameron 1983), traits (Denison and Mishra 1995), elements (Camerer 2003) as cited in Tandonet, (2018). The word culture has been derived from idea of cultivation which means the patterns of development. Sometimes known as "corporate culture" (Childress, 2013), corporate culture is used to denote the more commercialized meaning of organizational culture (Deal & Kennedy, 1982). A focus on organizational culture over the decade has increasingly become a major component of everyday organizational functioning because performance has been perceived to depend on the organization's culture. The performance management challenge has equally attracted attention of researchers in management. A study of culture within the organization shows that workers think the same way and are guided by the same ideas about the business (Racelis, 2010). There has been significant research in the literature to explore the impact of organizational culture on employee performance and productivity.

Organizational Culture, Maintenance and organizational Performance.

The concept of culture has various perspectives. However, for the purpose of this work, culture is perceived as a key that influences behaviour of getting things done the right way without which there is a hindrance of the attainment of goals. It is shaped by the interaction between individuals and groups that share the value, perception and goals they have assimilated from previous generation which continued in other generations. Culture in the context of a work organisation is put in place when social relationships among members influence their pattern of thinking and behaviour (Wilkins, 1994; Breden, 2006; Sani, Muhammed, Shukor, and Awang,, 2011). This implies that maintenance culture brings to bare the adoption of the attitude of ensuring regular servicing, repairs and maintenance of working assets or established system so as to guarantee their continuous usefulness.

In Nigeria, the concept seems to be very new. Manufacturing firms in Nigeria like Dangote Cement Company, Gboko, Benue breweries limited and Nigeria bottling company plc Makurdi have invested so much on infrastructure, equipment and machines but have not

given adequate attention to its maintenance and so very low results are realized in the use of assets, which lead to "poor maintenance culture." The situation in these firms can be attributed to poorly equipped maintenance departments, insufficient funding for operation and maintenance, lack of spare parts, transfer of plants without enough manpower requirements on ground, insufficient monitoring and lack of preventive and corrective maintenance strategies.

Corrective Maintenance and Organizational Effectiveness in Manufacturing Firms

Amaeshi, Okorocha and Akujor (2015) examined the effects of production facilities maintenance on the competitive advantage of selected process manufacturing firms in Nigeria focusing on the corrective, preventive, predictive, reliability center and total productive maintenance strategies and their relationship to cost of manufacturing operations, product quality, productivity target, on-time delivery and profitability has positive influence organizational effectiveness. The study adopted the descriptive survey method. Thirty copies of a structured questionnaire on five points Likert scale with Crombach alpha of 0.703 was used to obtain data from the study population of thirty (30) respondents across the various units in the study organizations and analyzed the data obtained with E-views software package in co-integration statistics. It was found out that corrective maintenance strategy has direct and indirect cost implications on manufacturing operations; positive significant relationship exists between corrective and preventive maintenance strategy and product quality determination; predictive maintenance strategy exerts positive influence on productivity target; reliability center maintenance significantly accounts for on-time delivery in meeting customers' expectation and total productive maintenance was equally found out to have positive effect on profit contribution. The study therefore recommended that every manufacturing firm should integrate maintenance budgets into organizational objectives and have functional maintenance centres; Manufacturing firms should be committed to high maintenance culture to minimize production losses and wastes. Preventive maintenance education and training should be given to every machine operator on regular basis and implementation of preventive maintenance actions be monitored by the head of maintenance department to reduce the chances of machine breakdown.

Preventive Maintenance and Organizational Efficiency in Manufacturing Firms

Maletic, Maletic, Al-Najjar and Gomiscek (2014) examined the role of preventive maintenance in improving company's competitiveness and efficiency. The paper aimed to discuss the potential improvement areas from the company perspective and to examine maintenance impact on company's business. An empirical case study was utilized aimed to provide an understanding of the role of maintenance in improving company's business. The empirical data for the study was collected from a Slovenian textile company. A gap analysis was used in order to address the research problem and to identify potential improvement areas. Based on the gap analysis, the results suggested that from respondents' points of view, preventive maintenance practices and condition-based maintenance (CBM) approach represent the highest opportunity for improvement organizational performance. The most notable empirical results of the study showed that around 3% of additional profit could be generated at weaving machine, especially if all unplanned stoppages and loss of quality due to decrease in the productivity would be prevented.

Condition-based Maintenance and Organizational Profitability in Manufacturing Firms
Otieno (2016) determined how the different condition-based maintenance practices have an impact on the operational performance of manufacturing firms listed in Nairobi Securities Exchange. It also sought to establish the extent of application of the various condition-based maintenance practices by the firms and the remedial actions taken. A questionnaire was designed and administered in order to achieve the above objectives. Data collected was analyzed using MS excel and Statistical Package for Social Sciences (SPSS). The findings reveal that 23.1% of the respondents use purely condition based maintenance while the rest use either preventive maintenance or a combination of the two maintenance policies. The study also shows that most of the firms use planned condition-based maintenance strategies and not unplanned. A relationship was also established between condition-based maintenance practices and the various variables of operational performance.

Pre-determined Maintenance and Organizational Performance in Manufacturing Firms
In order to achieve the optimal operation of machines, scheduled maintenance works are performed at fixed intervals regardless of other information. Nevertheless, Mann, (2001) claimed that the scheduled maintenance is based on the use of statistical and reliability analysis of system and component failure. Then, the fixed maintenance interval to replace or overhaul parts or components is established to achieve minimal maintenance expenditure. The interval of maintenance activities is vital, as inappropriate predetermined maintenance interval affects the maintenance outcome. Whereby, scheduled maintenance requires an intrusion of the system. It can only be back into operation upon completion of the maintenance. In some cases, often intrusion of the components may affect the effectiveness of the system. Moreover, Narayan (2011) revealed that unavailable or delayed action to perform maintenance task at the right time may cause further damages to the system components. It is necessary to apply appropriate preventive maintenance treatments at the right time to extend service life of the components. However, Yang (2008) argued that the scheduled maintenance programs might not be able to avoid the risk of failure from occurring in system components before the fixed replacement time. This problem occurs due to unknown condition of the system components. Direct maintenance cost will increase with a tight maintenance interval; while downtime and remedial cost due to system breakdown may be expensive with a loose maintenance interval. According to Bahrami (2001), if scheduled maintenance activity is performed rarely, downtime due to sudden breakdown will increase. On the other hand, if scheduled maintenance work is performed too frequently, downtime due to maintenance interruptions will increase. Moghaddam and Usher (2007) further explained that frequent maintenance or replacement enhances the reliability of a system, but it is costly at the same time.

Theoretical Framework

The Systems theory by Ludwig von Bertalanffy in (1940s)
This theory viewed the inputs/output models. The inputs are taken through process(es) to transform them to outputs. The outputs are compared with the objectives and feedback is send to the inputs to enhance improvement of efficiency and productivity of the system

(Ludwig, 1968). The concept of this theory was applied in maintenance management by Visser (2000). He noted that maintenance management being the system, the inputs were labour, materials, spares, tools, information and external services. The maintenance system processed these inputs into availability, maintainability, safety and profits as the outputs.
Systems theory is a concept that originated from biology, economics, and engineering, which explores principles and laws that can be generalized across various systems (Yoon and Kuchinke, 2005; Alter, 2007: 35; Dubrovsky, 2004). A system is a set of two or more elements where: the behaviour of each element has an effect on the behaviour of the whole; the behaviour of the elements and their effects on the whole are interdependent; and while subgroups of the elements all have an effect on the behaviour of the whole, none has an independent effect on it (Skyttner, 1996). In other words, a system comprises of subsystems whose inter-relationships and interdependence move toward equilibrium within the larger system (Martinelli, 2001; Steele, 2003).

METHODOLOGY

A survey research design approach was adopted for the study. The population of the study were made up of 540 management staff of selected manufacturing firms in Akwa Ibom State. The Taro Yamen technique was further employed to arrive at a sample size of 275 respondents for the study. These respondents were assessed from 5 branches of selected manufacturing firms using the systematic random sampling technique. Primary and secondary data were used and the primary data were generated through firsthand information gathered from the selected manufacturing firms in Akwa Ibom State. Secondary data were sourced from both published and unpublished papers and records on issues that border on the subject matter under study. Data collected from primary sources were further analyzed with the Ordinal Logistic Regression to ascertain the relationship that exist between the independent and dependent variables. The test will be carried out at a 95% Confidence interval, with 5% (0.05) level of significance. The reliability was determined through the Cronbach alpha reliability test. The resulting coefficient for 32 items was 0.861. Since the result co-efficient was above the threshold of 0.5, the instrument was ascertained reliable and adopted for the study.

Test of Hypotheses

The hypotheses were tested using the Ordinal Logistic Regression. The hypotheses were tested at 0.05 level of significance. The null hypotheses will be rejected if the probability value (p-value) is less than 0.05 ($p<0.05$).

H_{01}: There is no significant relationship between corrective maintenance and organizational Effectiveness in manufacturing firms.

Table 4.3.1 Relationship between corrective maintenance and organizational Effectiveness in manufacturing firms

Parameter Estimates

							95% Confidence Interval	
		Estimate	Std. Error	Wald	df	Sig.	Lower Bound	Upper Bound
Threshold	[Effectiveness = 1.00]	2.624	.443	35.140	1	.000	1.756	3.491
	[Effectiveness = 2.00]	3.972	.486	66.878	1	.000	3.020	4.924
	[Effectiveness = 3.00]	4.428	.503	77.472	1	.000	3.442	5.414
	[Effectiveness = 4.00]	6.061	.564	115.331	1	.000	4.954	7.167
Location	Corrective Maintenance	0.592	.134	107.219	1	.000	1.128	1.655

Link function: Logit.

From the analysis, the coefficient for the first hypothesis =0.590, suggesting a strong positive predictor between corrective maintenance and organizational effectiveness. The result was statistically significant (R= 0.592; n= 258; p= 0.000). Based on this, it is assume that corrective maintenance will influence organizational effectiveness since the p-value is less than 0.05(p=0.001<0.05). corrective maintenance was a significant positive predictor of organizational effectiveness. For every one unit increase in corrective maintenance there is a predictive increase of .590 in the log odds of being at a higher level organizational effectiveness.

H_{02}: There is no significant relationship between preventive maintenance and organizational efficiency in manufacturing firms.

Table 4.3.2 Relationship between preventive maintenance and organizational efficiency in manufacturing firms

Parameter Estimates

							95% Confidence Interval	
		Estimate	Std. Error	Wald	df	Sig.	Lower Bound	Upper Bound
Threshold	[Efficiency = 1.00]	1.621	.344	22.249	1	.000	.947	2.294
	[Efficiency = 2.00]	3.028	.390	60.187	1	.000	2.263	3.793
	[Efficiency = 3.00]	3.512	.410	73.394	1	.000	2.709	4.316
	[Efficiency = 4.00]	5.178	.473	120.084	1	.000	4.252	6.104
Location	Preventive Maintenance	1.456	.108	113.910	1	.000	.944	1.368

Link function: Logit.

From the analysis, the positive coefficient (value of 1.456) shows that for every one unit increase in Preventive maintenance there is a predictive increase of 1.456 in the log odds of being at a higher level of organizational efficiency. The result was statistically positive (R= 1.456; n= 258; p= 0.000). Based on this, it is assume that Preventive maintenance will influence organizational efficiency since the p-value is less than 0.05(p=0.000<0.05). thus the null hypothesis is the rejected and the alternate accepted that there is a significant relationship between preventive maintenance and organizational efficiency in manufacturing firm

H_{03}: There is no significant relationship between condition-based and organizational profitability in selected manufacturing firms.

Table 4.3.3: Relationship between condition-based and organizational profitability in selected manufacturing firms

Parameter Estimates

							95% Confidence Interval	
		Estimate	Std. Error	Wald	df	Sig.	Lower Bound	Upper Bound
Threshold	[Profitability = 1.00]	1.580	.342	21.320	1	.000	.909	2.251
	[Profitability = 2.00]	2.979	.388	59.002	1	.000	2.219	3.739
	[Profitability = 3.00]	3.458	.407	72.125	1	.000	2.660	4.256
	[Profitability = 4.00]	5.109	.469	118.658	1	.000	4.190	6.028
Location	Condition-based Maintenance	1.637	.107	112.528	1	.000	.927	1.347

Link function: Logit.

From the analysis, the coefficient (R) for the third hypothesis ($H0_3$) = 1.637, suggesting a strong correlation between condition-based maintenance and profitability. The coefficient (value of 1.637) shows that for every one-unit increase in condition-based maintenance there is a predictive increase of 1.637 in the log odds of being at a higher level of profitability. Since the p-value is less than 0.05(p=0.000<0.05), the null hypothesis is rejected and the alternative hypothesis is accepted. Therefore, there is a significant relationship between condition-based maintenance and profitability.

H_{04}: There is no significant relationship between corrective, preventive, condition-based and Predetermined maintenance and organizational performance in manufacturing firms**.**

Table 4.3.4: Relationship between corrective, preventive, condition-based and Predetermined maintenance and organizational performance in manufacturing firms.

Parameter Estimates

							95% Confidence Interval	
		Estimate	Std. Error	Wald	df	Sig.	Lower Bound	Upper Bound
Threshold	[Org.perf = 1.00]	2.203	.522	17.783	1	.000	1.179	3.227
	[Org.perf = 2.00]	3.627	.561	41.808	1	.000	2.527	4.726
	[Org.perf = 3.00]	4.148	.577	51.702	1	.000	3.017	5.278
	[Org.perf = 4.00]	5.846	.628	86.746	1	.000	4.616	7.076
	[Org.perf = 5.00]	18.213	30.678	.352	1	.553	-41.915	78.341
Location	Preventive	.590	.391	2.285	1	.001	-.175	1.356
	corrective	.842	1.662	2920.925	1	.000	-93.100	-86.584
	Condition based	.215	1.487	.021	1	.000	-3.130	2.699
	Pre-determined	.787	.000	.	1	.000	90.787	90.787

Link function: Logit.

From the analysis, the coefficient for the forth hypothesis suggesting a strong positive predictor between preventive and corrective maintenance. The result was statistically significant (R = 0.560; 0.842, n= 258; p= 0.001). condition-based and pre-determined maintenance also has a correlation coefficient of 0.215, and 789 respectively. Based on this, it is assume that condition-based and pre-determined maintenance will influence organizational performance since the p-value is less than 0.05(p=0.001<0.05). Pre-determined maintenance was a significant positive predictor of organizational performance. For every one unit increase in Pre-determined maintenance there is a predictive increase of 787 in the log odds of being at a higher level organizational performance.

H_{05}: There is no relationship between Organizational Culture, Maintenance Management and Organizational Performance

Table 4.3.5: Relationship between Organizational Culture, Maintenance Management and Organizational Performance

Parameter Estimates

							95% Confidence Interval	
		Estimate	Std. Error	Wald	df	Sig.	Lower Bound	Upper Bound
Threshold	[Org.Cul.= 1.00]	2.274	.481	22.350	1	.000	1.331	3.217
	[Org.Cul = 2.00]	3.687	.520	50.206	1	.000	2.667	4.706
	[Org.Cul. = 3.00]	4.201	.538	61.067	1	.000	3.147	5.254
	[Org.Cul. = 4.00]	5.879	.593	98.170	1	.000	4.716	7.042
	[Org.Cul. = 5.00]	10.647	.953	124.747	1	.000	8.779	12.515
Location	Maintenance mgt	.714	.331	4.661	1	.031	.066	1.362
	Organizational Performance	.620	.262	5.608	1	.018	.107	1.134

Link function: Logit.

From the analysis, the coefficient for the fifth hypothesis suggesting a strong positive predictor between organizational culture, maintenance management and organizational performance. The result was statistically significant as maintenance management (R = 0.714; n= 258; p= 0.001). and organizational performance is 0.620, n= 258; p= 0.001. Based on this, it is assume that organizational culture will influence maintenance management and organizational performance since the p-value is less than 0.05(p=0.001<0.05).

DISCUSSION OF FINDINGS

From the analysis, the coefficient for the first hypothesis =0.590, suggesting a strong positive predictor between corrective maintenance and organizational effectiveness. The result was statistically significant (R= 0.592; n= 258; p= 0.000). Based on this, it is assume that corrective maintenance will influence organizational effectiveness since the p-value is less than 0.05(p=0.001<0.05). corrective maintenance was a significant positive predictor of organizational effectiveness. For every one-unit increase in corrective maintenance there is a predictive increase of .590 in the log odds of being at a higher-level organizational effectiveness. The finding is in agreement with the work of Tijani, Adeyemi and Omotehinshe (2016) which stated that the attitude of Nigerians on maintenance culture such as corrective, preventive and predictive maintenance has positive affected infrastructural development which is critical and essential to a Nation's development. Also from Amaeshi, Okorocha and Akujor (2015) stated that selected process manufacturing firms in Nigeria focusing on the corrective, preventive, predictive, reliability center and total productive maintenance strategies and their relationship to cost of manufacturing operations, product quality, productivity target, on-time delivery and profitability has positive influence organizational effectiveness.

Based on the interview, respondents expressed that:

> "Corrective maintenance gives technicians the possibility to perform their interventions without delay, even if they can choose whether they want to maintain the piece of equipment on the spot, right when a problem has been detected or later".

Again another respondent expressed that:

> "You perform a Corrective maintenance to improve the working condition of the machine which in turn enhance effectiveness of the machine. It is performed when a malfunction is detected and machine is not operating properly as per designated function".

From the analysis, the coefficient for the second hypothesis (value of 1.456) shows that for every one-unit increase in preventive maintenance there is a predictive increase of 1.456 in the log odds of being at a higher level of organizational efficiency. The result was statistically positive (R= 1.456; n= 258; p= 0.000). Based on this, it is assume that Preventive maintenance will influence organizational efficiency since the p-value is less than 0.05(p=0.000<0.05). thus the null hypothesis is the rejected and the alternate accepted that there is a significant relationship between preventive maintenance and organizational

efficiency in manufacturing firms. This finding is in agreement with Okorocha and Akujor (2015) state that frequent machine breakdown and low plant availability are threats to a manufacturing concern as it affects the chances of meeting customers' requirements via cost of operations, product quality, quantity and on time delivery i.e efficiency, which are the baseline for profit determination. Availability here means readily obtainable, capable of being used for accomplishment of a purpose. Machine availability is the ability of the machines to be capable of being used for production; being readily obtainable when needed for production purposes. Maletic, Maletic, Al-Najjar and Gomiscek (2014) that preventive maintenance based on the gap analysis, the results suggested from respondents' points of view, preventive maintenance practices and condition-based maintenance (CBM) approach represent the highest opportunity for improvement organizational performance.

Based on the interview, respondents expressed that:

> "Even if preventive maintenance doesn't always allow maintenance teams to anticipate each breakdown or failure as it remains very difficult to know exactly which components are about to fail, it still helps them reduce their scope of errors".

From the analysis, the coefficient (R) for the third hypothesis ($H0_3$) = 1.637, suggesting a strong correlation between condition-based maintenance and profitability. The coefficient (value of 1.637) shows that for every one unit increase in condition-based maintenance there is a predictive increase of 1.637 in the log odds of being at a higher level of profitability. Since the p-value is less than 0.05($p=0.000<0.05$), the null hypothesis is rejected and the alternative hypothesis is accepted. Therefore, there is a significant relationship between condition-based maintenance and profitability.

From the interview, respondents expressed that,

> "A failure mode is a specific cause of the failure or one of the possible ways in which a system can fail. The more complex equipment, the more failure modes it can have. Understanding these failure modes and their impact will help you identify and adopt the right condition monitoring solution which is an important aspect of improving asset reliability".

From the analysis, the coefficient for the fourth hypothesis suggesting a strong positive predictor between preventive and pre-determined maintenance. The result was statistically significant (R = .560; 90.787, n= 258; p= 0.001). corrective and condition-based maintenance has a negative coefficient of -89.842, and -215 respectively. Based on this, it is assume that pre-determined maintenance and preventive maintenance will influence organizational performance since the p-value is less than 0.05($p=0.001<0.05$). Pre-determined maintenance was a significant positive predictor of organizational performance. For every one unit increase in Pre-determined maintenance there is a predictive increase of 90.979 in the log odds of being at a higher level organizational performance. Otieno (2016) determined how

the different corrective maintenance practices have an impact on the operational performance of manufacturing firms listed in Nairobi Securities Exchange. It also sought to establish the extent of application of the various corrective maintenance practices by the firms and the remedial actions taken. Okorocha and Akujor (2015) state that frequent machine breakdown and low plant availability are threats to a manufacturing concern as it affects the chances of meeting customers' requirements via cost of operations, product quality, quantity and on time delivery, which are the baseline for profit determination. Okorocha and Akujor (2015) state that frequent machine breakdown and low plant availability are threats to a manufacturing concern as it affects the chances of meeting customers' requirements via cost of operations, product quality, quantity and on time delivery, which are the baseline for profit determination

From the analysis, the coefficient for the fifth hypothesis suggesting a strong positive predictor between organizational culture, maintenance management and organizational performance. The result was statistically significant as maintenance management (R = 0.714; n= 258; p= 0.001). and organizational performance is 0.620, n= 258; p= 0.001. Based on this, it is assume that organizational culture will influence maintenance management and organizational performance since the p-value is less than 0.05 (p=0.001<0.05).

CONCLUSION

Base on the findings, the following conclusions are drawn;

From the study conducted, it is obvious that preventive, corrective, condition-based and predetermined maintenance are relational dimensions that can influence organizational performance among manufacturing firms in Akwa Ibom State, Nigeria. The empirical results of the study clearly underscore the following:

i. Preventive, corrective, condition-based and pre-determined maintenance are significant predictor of organizational performance.
ii. Companies that consider the application of maintenance dimensions are likely to record a better Key Performance Indicator (KPI).
iii. Although all four maintenance management dimensions were strongly correlated, the coefficient for corrective maintenance was seen as the dimension that had the highest significant influence at 0.842 on the firms performance.

The strong and positive outcome evident in the results of coefficient shows that the influence of maintenance management dimensions on organizational performance did not happen by chance.

Recommendations

Management should ensure that Corrective maintenance is implemented right after a defect has been detected on a piece of equipment or a production line: its objective is to make the piece of equipment work normally again, so that it can perform its assigned function. Corrective maintenance can either be planned or unplanned depending on whether or not a maintenance plan has been created.

Management should use preventive maintenance applied by applied by technician's teams and managers before any breakdown or failure occurs. Its aim is to reduce the probability of

breakdown or degradation of a piece of equipment, component or spare part. In order to implement such maintenance, teams have to take the part's history into consideration and keep track of the past failures.

MANAGEMENT should ensure that all this data are gathered automatically on the field or remotely thanks to a direct network connection to the equipment, in order to make sure that it is constantly controlled. Maintenance teams can decide whether they want to operate constant or regular interval control: they read counters, check parts' wear, control motors' temperatures.

References

Al-Najjar, B. and Alsyouf, I. (2003), "Selecting the most efficient maintenance approach using fuzzy multiple criteria decision making", *International Journal of Production Economics, Vol. 84 No. 1, 85–100*

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, Vol. 107 No. 1, pp. 260–273.*

Al-Najjar, B. and Alsyouf, I. (2004), Cost effective maintenance for competitive advantages. *Doctoral dissertation,Vaxjo University, Vaxjo*

Al-Turki Ayer, A and Ben-Daya, M. (2014), "Total maintenance management: a systematic approach", *Journal of Quality in Maintenance Engineering, Vol. 1 No. 1, pp. 6-14.*

Barney D (1991) *An introduction to maintenance scorecard*. The plant maintenance News letter edition 52, dated 13 April 2005. Murthy DNP

Ben-Daya, M. and Duffuaa, S.O. (2005), "Maintenance and quality: the missing link", *Journal of Quality in Maintenance Engineering, Vol. 1 No. 1, pp. 20-6.*

Buchanan, G. and Besant, L. (1985), "A framework for maintenance concept development", *International Journal of Production Economics, Vol. 77 No. 3.*

Coase A. S. (1937) A performance measurement paradigm for integrating strategy formulation: *a review of systems and frameworks. int J of manag rev 7: 49–71*..

Daya H. P, (2000) Development and implementation of maintenance performance indicators for the Norwegian oil and gas industry. *Proceedings of the 14th International Maintenance Congress (Euro maintenance 2000), 7–10 March 2000, Gothenburg, Sweden, pp 221-228.*

Danny A. (2003) Role of condition monitoring and performance measurement in asset productivity enhancement. *Proceedings of the 19th International Congress COMADEM, 12–14 June 2007, Porto, Portugal, pp 525–531.*

Dilworth, S. (1992), "Demystifying productivity and performance*", International Journal of Productivity and Performance Management, Vol. 54 No. 1, pp. 34-46.*

Douglas JA (2010) *Strategic maintenance management*. J of Qual in Maint Eng 8(4): 287–305. Neely AD,

Eti, J., Ogaji, J. and Probert, U. (2004), "A situational maintenance model", *International Journal of Quality and Reliability Management, Vol. 14 No. 4, pp. 349–366.*

Fore R. L. and Zuze K.F (2010) *Measure up!* The Essential Guide to Measuring Business Performance, Mandarin: London.

Gomes A, Chattopadhyay G and Kumar U (2011) Multi criteria maintenance performance measurement: a conceptual model. *Proceedings of the 18th International Congress COMADEM, 31st Aug-2nd Sep 2005, Cranfield, UK, pp 349–356*.

González-Prida, V. and Crespo Márquez, A. (2012). "A framework for warranty management in industrial assets", Computers in Industry, Vol. 63 No. 9, pp. 960–971.

Gupta, B. B., Schroeder, R. G. and Sakakibara, S. (2005), "A Framework for Quality Management Research and an Associated Measurement Instrument", *Journal of Operations Management, Vol. 11 No. 4, pp. 339-366.*

Hannequin, M. and Aranjo, S. (2009), "Selection of maintenance policy for textile industry using hybrid multi-criteria decision making approach", *Journal of Manufacturing Technology Management, Vol. 20 No. 7, pp.1009 – 1022*

Hiplain, V. and Decock, A. (2000). "A framework for warranty management in industrial assets", Computers in Industry, Vol. 63 No. 9, pp. 960–971.

Khan, M. R. R. and Darrab, A. I. (2010), "Development of analytical relation between maintenance, quality and productivity", *Journal of Quality in Maintenance Engineering, Vol. 16 No. 4, pp. 341-353.*

Lucky, H. (2011), "Management of industrial maintenance-economic evaluation of maintenance policies", *International Journal of Operations &Production Management, Vol. 19 No. 7, pp. 716–737.*

Lucky, M. and Manai, B. (2011), "The relationship between continuous improvement and maintenance performance", *Journal of Quality in Maintenance Engineering, Vol. 18 No. 1, pp. 30 – 41.*

Ludarig K (1968) Performance Measurement System Design – A Literature Review and Research Agenda. Int J of Oper and Prod Manag 15(4): 80–116.

Manni, K.E., Schroeder, R.G. and Cua, K.O. (2000), "The impact of total productive maintenance practices on manufacturing performance*", Journal of Operations Management, Vol. 19 No. 1, pp. 39–58. Mitchell*

Marques, D.S., and Gupta, S.J. (2006), "*Productivity measurement and evaluation*: What is available?", National Productivity Review, Vol. 3 No. 3, pp. 265-287.

McKone, K.E., Schroeder, R.G. and Cua, K.O. (2001), "The impact of total productive maintenance practices on manufacturing performance", *Journal of Operations Management, Vol. 19 No. 1, pp. 39–58.*

Maletič M., Al-Najjar B. and Gomišček B. (2015), "The Role of Maintenance Regarding Improving Product Quality and Company's Profitability: A Case Study", in 2nd IFAC Workshop on Advanced Maintenance Engineering, Services and Technology, Universidad de Sevilla, Sevilla, Spain. November 22-23, 2012, pp. 7-12

Maletic R S and Norton DP (2014*) Strategy Map*: Converting intangible asset into tangible outcomes, Harvard Business School Press, USA Kelly A (1997) Maintenance Organization and System., Butterworth Heinemann, UK.

Murthy, R. (2005), "Overall equipment effectiveness as a measure of operational improvement - A practical analysis", *International Journal of Operations & Production Management, Vol. 20 No. 12, pp. 1488 – 1502*

Nakajima, S. (2008), *Introduction to Total Productive Maintenance*, TPM. Productivity Press, Cambridge.

Ngatia, A. (2013), *Maintenance Organization and Systems*: Business Centred Maintenance, Butterworth-Heinemann, Oxford.

Nwele D. P (2016) *The balanced scorecard* – measures that drive performance. Harvard Business Review, pp 71–79.

Okorocha J.P. and Akuja U. (2015) Towards a value-based view on operations and maintenance performance management. J of Qual in Maint Eng 9: 333–350

Panner, Selvan. (2009), "A framework for managing maintenance using performance measurements systems", International Journal of Operations & Production Management, Vol. 21 No. 1, pp. 173-95.

Parida, A. (2007), "Study and analysis of maintenance performance indicators (MPIs) for LKAB",*Journal of Quality in Maintenance Engineering, Vol. 13 No. 4, pp. 325-37.*

Parida, A. and Chattopadhyay, G. (2007), "Development of a multi-criteria hierarchical framework for maintenance performance measurement (MPM)", *Journal of Quality in Maintenance Engineering, Vol. 13 No. 3, pp. 241-258*

Pintelon, L. and paradi, A. (2008), "An empirical investigation on the relationship between business and maintenance strategies", *International Journal of Production Economics, Vol. 104 No. 1, pp. 214–229*

Rastegari, L. and Salonan, G. (2013), "A practical approach to maintenance modelling", in: J. Ashayeri, W.G. Sullivan, M.M. Ahmad (Eds.), Flexible Automation and Intelligent Manufacturing, Begell House Inc., New York, pp. 1109–1119.

Simoes, N.M., Gomes, W. and Yasin (2011), "Maintenance scheduling: issues, results and research needs," *International Journal of Operations and Production Management, Vol. 14 No. 8, pp. 47-69.*

Smith, M. (2002), "A simple method to link productivity to profitability", Management Accounting Quarterly, Summer, Vol. 1 No. 4, pp. 12-17.