ANALYZING ADOPTION OF MAINTENANCE STRATEGIES IN MANUFACTURING COMPANIES

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ABSTRACT

Maintenance is the combination of all technical and associated administrative actions intended to retain an item in, or restore it to, a state in which it can perform its required function. Companies are seeking to gain competitive advantage with respect to cost, quality, service and on time deliveries. The effect of maintenance on these variables has prompted increased attention to the maintenance areas as an integral part of productivity improvement. Due to numerous advantages of maintenance, manufacturing companies are trying to adopt maintenance strategies to support their businesses. The purpose of this study is to analyze maintenance strategies found in local manufacturing companies. In this paper we report on our findings on how maintenance strategy has improved company operations and performance.

The paper is based on maintenance strategy theoretical overview and multiple case studies in which six companies were studied. The paper evaluates their views on the strategic impact of production maintenance. From literature two important elements of maintenance strategy that were focused on are structural and infrastructure decisions. A benchmarking process was also done on maintenance performance factors. A questionnaire that incorporated structural, infrastructural and maintenance performance factors was circulated in the studied companies.

The research established that most employees now understand maintenance policies and concepts. An increase in in-house maintenance was observed, with improved overall equipment effectiveness. Improved spares availability was also noticed. The study noticed that equipment modifications was still lacking in most companies. Most maintenance personnel had no access to the computerized maintenance management systems, impacting negatively on their maintenance planning and control. The paper recommends that employees with design background must be incorporated into maintenance teams. Employees must be trained on computerized maintenance management systems.

This paper contributes to the understanding of maintenance management constructs and the factors influencing the implementation of maintenance strategies.

Key words: Maintenance strategy, competitive advantage, manufacturing, management.

INTRODUCTION

In recent years, there has been an increasing concentration in maintenance within the business sector. This is as a result of escalating pressure upon manufacturing organizations to meet customer and corporate demands, as well as improving equipment availability and performance (Baglee and Knowles, 2010). Therefore, maintenance with its various activities, resources, measurement and

management, has become critical to manufacturing organizations (Simoes et al., 2011). In this respect, maintenance have come to play an important role in helping organizations to reach their goals of productivity, profitability and competitiveness and making sure that their equipment operates effectively and efficiently (Baglee and Knowles, 2010). The scope of maintenance has moved from a narrow- defined operational view, to an organizational strategic view, with the increasing awareness that maintenance creates added value to the business process (Liyange and Kumar, 2003).

Previous studies have reported that, maintenance account between 15% - 70% of the total production cost (Bevilaqua and Bragila, 2000). In manufacturing organizations, maintenance related costs are estimated to be 25% of the overall operating costs (Komonen, 2002; Simoes et al., 2011). It is further reported that about 30% of maintenance costs are related to unnecessary expenditures, due to bad planning, overtime and unmet preventive maintenance (Salonen and Deleryd, 2011).With maintenance cost accounting for such a large portion of production cost, it is essential that the strategic management and development of maintenance be considered (Baglee and Knowles, 2010). It is becoming increasingly difficult to ignore maintenance as organizations are treating maintenance as an integral part of their business. However, the recent trends have indicated that in general, many manufacturing systems are not performing as intended, so far as cost effectiveness in terms of their operation and support (Chan et al., 2005).

Most companies are now replacing their ancient strategies of maintenance with proactive strategies like Preventative and Predictive Maintenance and aggressive strategies like Total Productive Maintenance (TPM) (Swanson, 2001). These modern maintenance practices have allowed organizations to strategically direct their resources to the maintenance tasks that are considered critical to the effective and efficient running of their equipment (Baglee and Knowles, 2010). By introducing TPM within manufacturing industry, a number of organizations have claimed improvements in equipment availability, reliability and a reduction in maintenance costs (Cooke, 2000). Cholasuke et al., (2004); Baglee and Knowles, (2010), described the benefits of TPM as increased product quality, equipment availability and a reduction in operating costs. Consequently, production systems now need to be perfected in line with new trends of doing business with minimum unforeseen disturbances.

Measuring maintenance productivity performance is critical for any production and operational company, hence, a measure commonly used by industries is the maintenance performance for measuring the maintenance productivity, (Ben-Daya et al., 2009). Literature suggests that performance measurement has caught the imagination and involvement of researchers and managers from the industry since 1990s (Kumar et al., 2014). Performance measurement is a means to measure the implementing strategies and policies of the management of the organization, which is the characteristics of Maintenance Performance Measurement (MPM), (Ben-Daya et al., 2009). MPM allows companies to understand the value created by maintenance, to re-evaluate and revise their maintenance policies and techniques, justify investment in new trends and techniques, revise resource allocations, and to understand the effects of maintenance on other functions and stakeholders as well as on health and safety (Parda and Kumar, 2006). An important aspect of MPM is formulating maintenance performance indicators, linking maintenance strategies with overall organizational strategy (Tsang, 2002).

The measurement of maintenance performance has essentially become a critical component of strategic thinking for service and manufacturing industry. The performance of the maintenance

process is critical for the long term value creation and economic feasibility of many industries. It is important that the performance of maintenance process be measured, so that it can be controlled and monitored for taking appropriate and corrective actions to minimize and mitigate risks in the area of safety, meet societal responsibilities and enhance the effectiveness and efficiency of the asset maintained (Ben-Daya et al., 2009). The major issue in measuring maintenance performance is the formulation and selection of maintenance performance indicators that reflect a company's organizational strategy and give maintenance management quantitative information on the performance of the maintenance strategy (Swanson, 2001).

Despite the overwhelming benefits gained through effective performance measurement and management, and the fact that organizations using integrated balanced performance management systems tend to outperform their counterparts (Parida and Kumar, 2006), studies have shown that 70% of all those systems implementation initiatives have failed (Bourne, 2005). Only one – third of the organizations with good maintenance management practices tended to realize the full benefits of their maintenance management initiatives (Simoes et al., 2011). According to Garg and Deshmukh (2006), this led to some researchers to advocate the utilization of broader and innovative performance management approaches, such as the Balance Scorecard and new organizational improvement instruments. The need for maintenance managers to receive appropriate formal educational training, which incorporate the different facets of their organizational roles, is becoming more important, as maintenance managers are being called upon to integrate and direct the maintenance efforts to meet organizational strategic goals efficiently and effectively (Alsyouf, 2007).

Six companies were case studied, they are into manufacturing of different products and their summary is as follows:

Case Study A: A general engineering manufacturing company was analyzed in the first case.

Case Study B: The Company is into security products and equipment manufacturing.

Case Study C: The study concerned a cable manufacturing company for automotive products.

Case Study D: The Company is into designing and manufacturing of defense systems and equipment.

Case Study E: The case study concerned a company into steel making.

Case Study F: The last case study concerned a motor manufacturing company.

RESEARCH OBJECTIVES

The main objective of this research is:

- To analyze adopted maintenance strategies in local manufacturing companies.

The sub objective of the research is:

- To evaluate how the adopted maintenance strategies has improved company operations and performance.

RESEARCH QUESTIONS

The research study seeks to answer to the following major question:

- To what extent does a maintenance strategy influence manufacturing operations?

In seeking answers to the above major question this study seeks to address the following sub questions:

- What are the aspects covered by a maintenance strategy?
- What is the relationship between manufacturing and maintenance strategy?

LITERATURE REVIEW

Maintenance Definition

According to a definition provided by Rastegari and Salonen (2013), 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". 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 et al., 2014). Maintenance also includes engineering decisions and associated actions that are necessary for the optimization of specified equipment capability, where capability is the ability to perform a specified function within a range of performance levels that may relate to capacity, rate, quality, safety and responsiveness (Kumar et al., 2014).

Khairy (2008), describes the key objective of maintenance as "total asset life cycle optimization which means maximizing the availability and reliability of the assets and equipment to produce the desired quantity of products, with the required quality specifications, in a timely manner and this objective must be attained in a cost-effective way and in accordance with environmental and safety regulation."

Maintenance Types

Maintenance is classified into two main categories, which are as follows (Al-Turki et al., 2014., Rastegari and Salonen, 2013)

- "Preventive maintenance is intended to reduce the probability of failure or degradation of functioning of an item and is carried out at predetermined intervals or according to a prescribed condition.
- Corrective maintenance, similar to repair work, is undertaken after a breakdown when obvious failure has been allocated".

Figure 1 represents an overview of maintenance types and their relations.

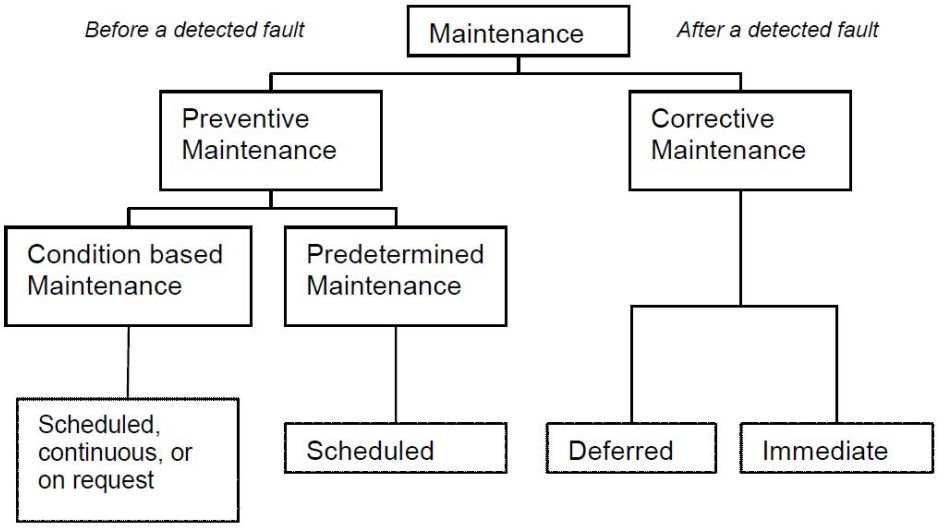

Figure 1: Maintenance types, Source: Rastegari and Salonen, 2013

Maintenance Strategy

Fredriksson and Larsson (2012), defines maintenance strategy as "the management method used in order to achieve the maintenance objectives". According to Bergman and Klefsjo (2010), the content in the maintenance strategy is a mix of techniques and/or policies which depends on factors such as the nature of the plant, the maintenance goals or the equipment that will be maintained, the work environment and the work flow patterns. Rastegari and Salonen (2013), states that "the strategy reflects the organizations conception of its intended long – term goal and the approach to achieve it". Maintenance strategies are a means of transforming business priorities into maintenance priorities (Salonen, 2011). By addressing current or potential gaps in maintenance performance, a generic maintenance plan will be developed.

Maintenance Concepts

Total Productive Maintenance (TPM)

Various concepts have been developed to increase effectiveness of maintenance activities with the two common concepts discussed in literature as, Reliability Centered Maintenance (RCM) and Total Productive Maintenance (TPM), (Rastegari and Salonen (2013).

The term "TPM" is used by Prabhuswamy et al., (2013) to refer to a "system of maintaining and improving the integrity of production and quality systems through the machines, equipment, processes and employees that add business value to the organization". Fredriksson and Larsson (2012) describes TPM "as a proactive and cost-effective approach to maximize equipment effectiveness using the principles of teamwork, empowerment, zero breakdowns, zero defects and zero accident". Ben-Daya et al., (2009) suggests that "TPM as the name suggests consists of three words which are:

Total: signifies to consider every aspect and involving everybody from top to bottom;

Productive*:* emphasis on trying to do it while production goes on and minimize troubles for production; and

Maintenance*:* means equipment upkeep autonomously by production operators in good condition – repair".

TPM is designed to maximize equipment effectiveness (improving overall efficiency) by establishing a comprehensive productive-maintenance system covering the entire life of the equipment, spanning all equipment related fields (planning, use, maintenance, etc.) and, with the participation of all employees from top management down to shop-floor workers, to promote productive maintenance through motivation management or voluntary small-group activities (Al-Turki et al., 2014).

The Figure below, shows the eight pillar approach for TPM implementation.

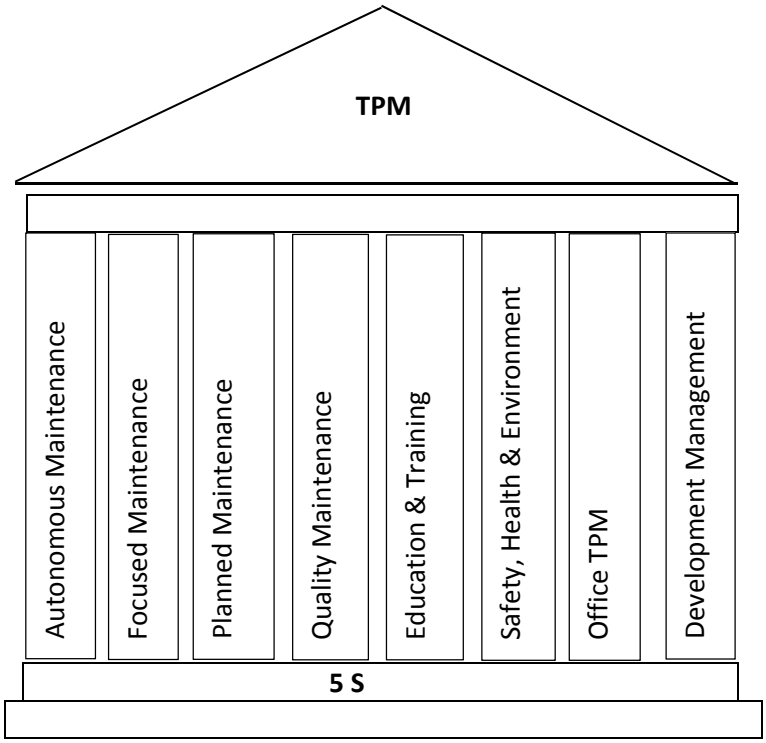

Figure 2: Eight pillar approach for TPM implementation, Source: Ben-Daya et al, 2009

TPM can improve dimensions of cost, quality, and delivery and it can be a strong contributor to the strength of the organization. In essence TPM is an approach which seeks to develop maintenance practices through a combination of measurement, planning, training, and the active involvement of a broader range of employees in addition to maintenance personnel in maintenance related activities (Baglee and Knowles, 2010).

Reliability Centered Maintenance (RCM)

Rastegari and Salonen (2013), defines RCM as " a process used to determine what must be done to ensure that any physical asset continues to do what its user wants it to do in its present operating context". A failure of one component may stop a whole plant from performing to the standard required by its users.

RCM is a systematic approach for understanding the function of the manufacturing system and the failure modes of its components, and choosing the optimum course of action that would prevent the failure modes from occurring or to detect them before occurring (Eti et al., 2006). RCM is a process

used to determine the maintenance requirements of physical asset in its operating context by identifying the functions of the asset, the causes of failures, and the effects of the failures (Ben-Daya, 2009).

As illustrated in the Figure below, Pride (2011) expresses an overview of RCM.

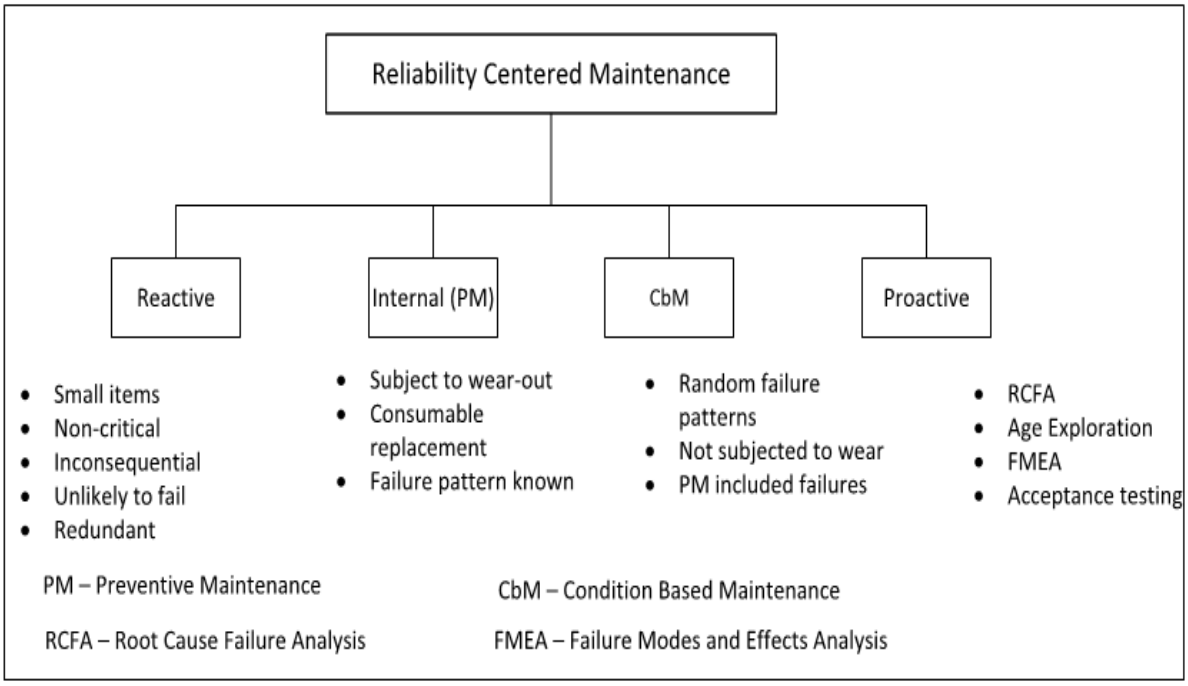

Figure 3: Overview of RCM, Source: Pride, 2011

According to (Siddiqui & Ben-Daya, 2009) the primary RCM principles are as follows:

i. Preserving the system functions is the first principal feature of RCM process. This feature is important in its understanding. It must be stressed, as it forces a change in the typical view of equipment maintenance and replaces it with the view of functional preservation. What is required is to identify the desired system output and ensure availability of the same output level.

ii. Identification of the particular failure modes that can potentially cause functional failure is the second feature of RCM process. This information is crucial whether a design or operational modification is required or a maintenance plan is to be made.

iii. Prioritizing key functional failures is the third of the RCM process features. This feature is of foremost importance as the philosophy of efficiency with cost effectiveness can be achieved through this feature. Efforts and resources are dedicated to equipment supporting critical functions and their unavailability means major degradation of plant to even total shutdown.

iv. Selection of applicable and effective maintenance tasks for the high priority items is the fourth feature of the RCM process. The purpose of prioritizing is to make an efficient and cost effective use of resources.

Maintenance Management

Maintenance management must align with the business activities. Maintenance planning is done at three levels, strategic, tactical and operational levels as shown in the figure below.

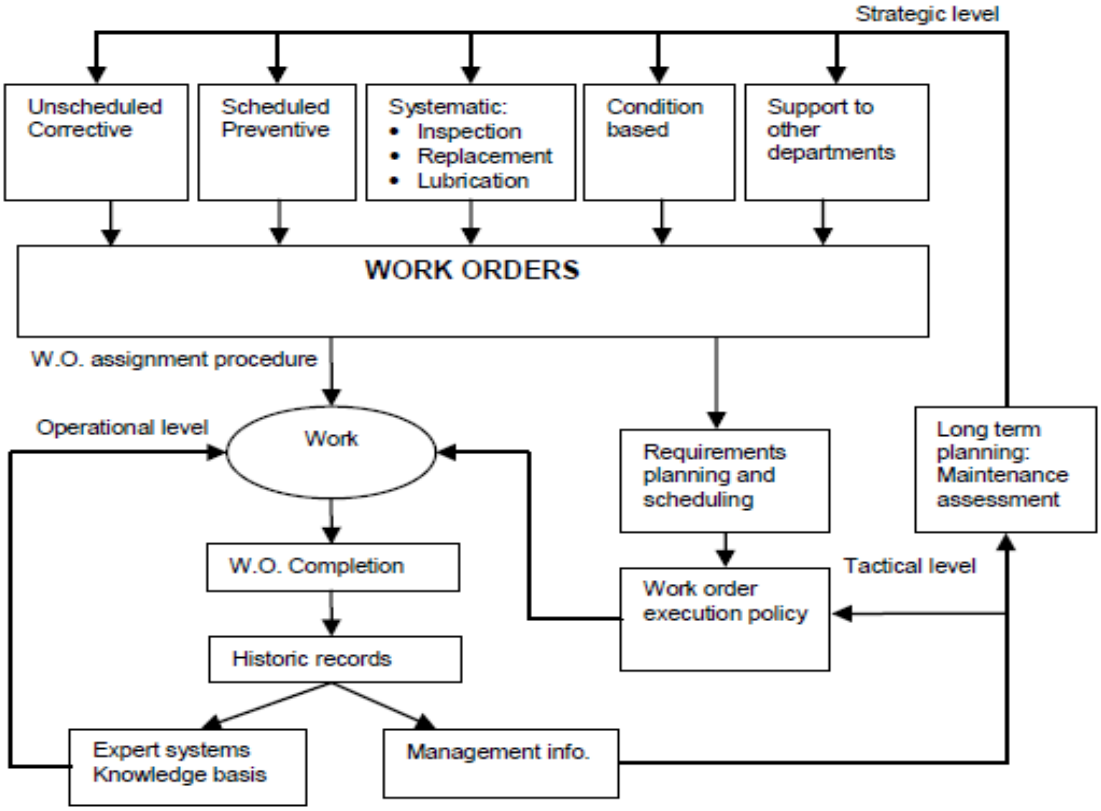

Figure 4: Maintenance Process, Source: Crespo Marquez and Gupta, 2006

Labib (2004) articulates "an increase in the amount of information available and an increasing requirement to have this information on hand and in real-time for decision-making indicates the need to have Computerized Maintenance Management System (CMMS) to aid maintenance management". Rastegari and Salonen (2013) concludes that CMMS can provide the following benefits:

- "Support condition based monitoring
- Track the movements of spare parts
- Allow workers to report faults faster
- Improve communications between operations and maintenance personnel
- Provide maintenance managers with information to have better control of their departments".

Maintenance Performance Measurement

Maintenance Performance Measurement (MPM) is defined as "the multidisciplinary process of measuring and justifying the value created by maintenance investment and taking care of the organizations stockholders requirements viewed strategically from the overall business perspective"

(Parida and Chattopadhyay, 2007). Parida and Kumar (2006) discusses the importance of MPM as follows:

- "Allows companies to understand the value created by maintenance
- Re-evaluate and revise maintenance policies and techniques
- Justify investment in new trends and techniques
- Revise resource allocations and to understand the effects of maintenance on their functions and stakeholders as well as on health and safety".

Different categories of maintenance performance measures/indicators are identified in literature. Kumar et al., (2014) classified the commonly used measures of maintenance performance into three categories based on their focus and these categories are (1) measures of equipment (2) measures of cost and (3) measures of process performance.

Webber and Thomas (2006) states that "the commonly used maintenance performance indicators are maintenance process/effort indicators which are defined as leading indicators and maintenance results indicators defined as lagging indicators", as shown in the figure below.

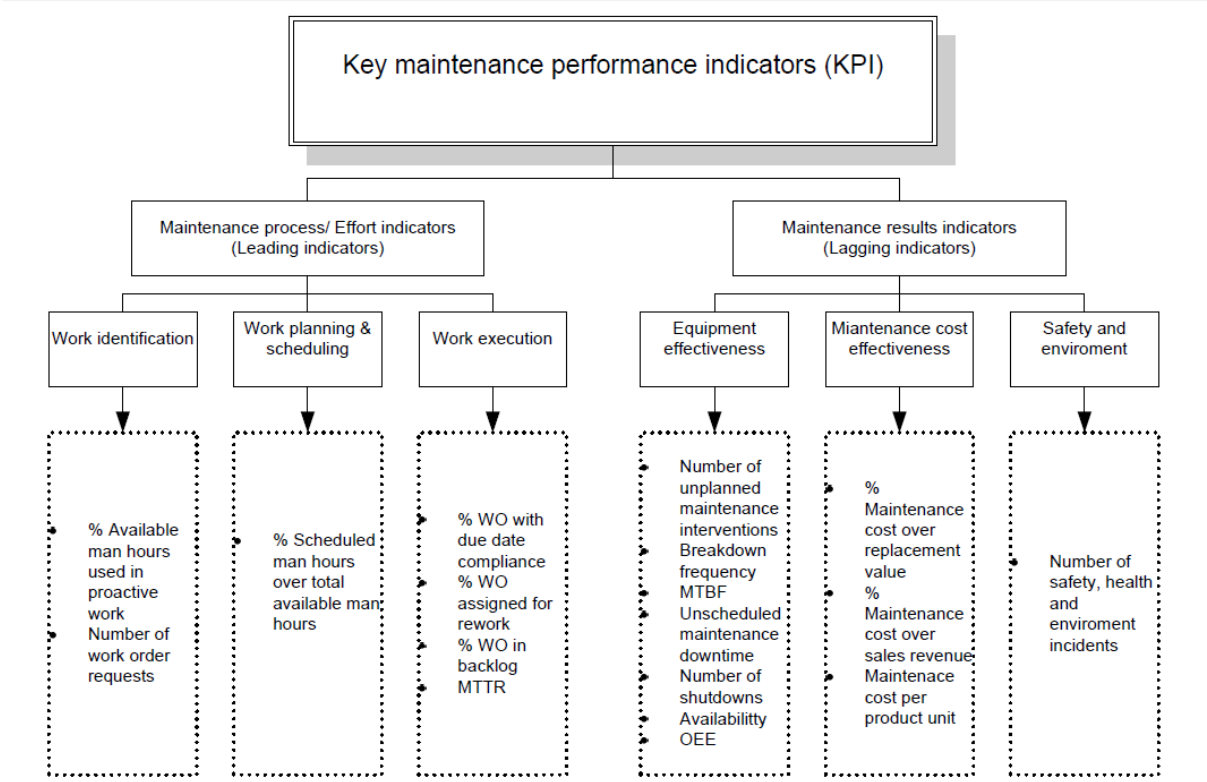

Figure 5: Key Maintenance Performance Indicators, Source: Kumar et al, 2014

Leading indicators are indicators which measures performance before a possible problem/failure arise, whereas lagging indicators indicates that the problem/failure has arose (Smith, 2004). Salonen and Bengtsson (2007) expresses that "Reliability is a measured by Mean Time Between Failure (MTBF), Maintainability by Mean Time To Repair (MTTR) and Maintenance Supportability by Mean Waiting Time (MWT)".

Overall Equipment Effectiveness (OEE)

OEE is a method to understand the performance of the manufacturing area, but also to identify possible limitations (Hansen, 2002). OEE calculates the percentage effectiveness of the manufacturing process. OEE is further a function consisting of the three factors, availability, performance efficiency and quality (Fredriksson and Larsson, 2012).

According to Kumar et al., (2014), the most popular set or list of indicators is a scorecard. The Balanced Scorecard (BSC) provides a presentation of strategic performance measures from four perspectives (i) financial (ii) customers (iii) internal processes and (iv) learning and growth (Eti et al., 2006). By using the BSC, the strategy becomes more tangible and actionable with respect to strategic objectives, the related performance measures, their targets and action plans.

Benchmarking

According to (Eti et al., 2006) benchmarking has been promoted as a technique that when implemented brings improvements in quality, productivity and efficiency to an organisations business processes by learning from the reasons for other organisations successes and the application of these practices in one's firm. In ensuring the maintainability and reliability of equipment, benchmarking can also be a useful tool.

RESEARCH METHODOLOGY

The research methodology of this research included relevant literature review and a detailed case study on six companies. Case studies can be used to explore, describe, explain and compare (Yin, 2009). The data was collected through a survey with well-structured questionnaires. The questionnaire type which was selected was a self- administered questionnaire which allows the interviewee to answer sensitive topics comfortably. The method which is proposed hereafter is based on an analysis of the adoption of maintenance strategies in six companies. Hayes and Wheelwright's four-stage model (1984) adapted from Pintelon et al., (2006) was applied in analysing adoption of maintenance strategies in six manufacturing companies. The questionnaire consists of 4 sections. In section 1 the maintenance strategy adopted by the company is to be indicated. Section 2 deals with questions concerning maintenance strategy decision elements. Approaches such as structural and infrastructural decision elements will be considered in detail concerning their performance, implementation and availability (Madu, 2000). Using a scale of 1-5, section 3 is based on ranking how each company assess its maintenance performance. Finally section 4 indicates the three areas that each company considers most important for the organization to focus on, in-order to achieve their goals. A scale of 1-3 is used, where 1 represent most important, 2 represent second most important and 3 represent third most important. A copy of the questionnaires is attached as Appendix A. 60 questionnaires were sent to the six companies. The total number of respondents was 28. Table 1 below shows the distribution of the response rate with respect to each company.

Table 1: response rate for questionnaires

Company	Sent questionnaires	Received questionnaires
A	10	4
B	10	5
C	10	4
D	10	5
E	10	5
F	10	5

FINDINGS

The effectiveness of maintenance can be identified if one is able to classify and assess a specified maintenance strategy. All the six manufacturing companies studied in this paper were analysed on the given current position of maintenance. Hayes and Wheelwright's four-stage model (1984) used by Pintelon et al., (2006), was adapted in analysing the adoption of maintenance strategies in the manufacturing companies. This model will assist as an evaluating tool to assess all strategies. An analysis of adopting maintenance strategies will be presented in the following sections. In all companies the questionnaire was filled by the maintenance team led by their maintenance managers. These companies are of different sizes.

Hayes and Wheelwrights four stage framework

Pintelon et al., (2006) states that "there are four stages that are identified which can reveal the firms position and the required transformations in order to move it to the next stage or to keep it from sliding to a lower stage". Barnes et al., (2001) summarize the four stage model as follows;

- "Firms in stage 1 and 2 can be characterized as having reactive strategies and they outsource majority of their maintenance activities. In general, stage 1 companies do not manage maintenance professionally. They try to minimize maintenances negative potential.
- Stage 2 firms go beyond the steps taken by stage 1 firms and try to neutralize competitors for any competitive advantage they may have. They consider their competitors as a benchmark and try to follow them.
- For stage 3 firms, the responsibilities placed on manufacturing are significant in comparison with the first two stages. They plan and schedule their maintenance activities. They equip maintenance with necessary expertise, skills and training to perform complex maintenance tasks.
- The fourth stage firms, gives manufacturing a central role in the formulation and implementation of competitive strategies. Stage 4 companies carry out continuous improvements, equipment modifications and develop new maintenance tools and practices to maintain world-class excellence in maintenance".

Company A

Key: RCM = Reliability Centred Maintenance, PDM = Predictive Maintenance,

TPM = Total Productive Maintenance, CM = Corrective Maintenance,

PM = Preventive Maintenance

Table 2: Company A Maintenance Strategy

Maintenance Strategy for Company A	
Maintenance capacity	15 with temporary workers
Maintenance facilities	Sometimes make own spare parts
Maintenance technology	10% usage of Predictive maintenance
Vertical integration	80% outsourced
Maintenance organization	Centralised
Maintenance procedures and concepts	CM 55%, TPM 45%
Maintenance planning and control systems	No planning
Manpower	Fewer competent staff, low training (9 hours per year), No joint effort in maintenance.
Maintenance modifications	No machinery adjustment
Maintenance performance measurement	Overall Equipment Effectiveness (OEE) at 35%

With reference to the Hayes and Wheelwrights four stage model (1984) used by Pintelon et al., (2006), Company A is on stage 1. The company sells its products as demand exceeds supply. Company A considers maintenance as a secondary function and has no formal strategy. The company outsources 80% of its maintenance activities, supporting the fact that their maintenance activities are not yet developed. They rely on external maintenance service personnel in solving difficult equipment problems. This implies the fact that the company does not manage maintenance professionally. Company A lacks focus in training and education. Skills are necessary as they support quality improvement efforts. This case study shows that the company is neglecting the strategic importance of the maintenance function.

Company B

Table 3: Company B Maintenance Strategy

Maintenance Strategy for Company B	
Maintenance capacity	12 with temporary workmen
Maintenance facilities	Sometimes make own spare parts
Maintenance technology	Condition monitoring not used
Vertical integration	60% outsourced
Maintenance organization	De- centralised

Maintenance Strategy for Company B	
Maintenance procedures and concepts	TPM 40%, CM 60%,
Maintenance scheduling and monitoring	No planning
Manpower	20% professional staff, low training
Maintenance modifications	No equipment modification
Maintenance performance measurement	Overall Equipment Effectiveness (OEE) at 30%

Company B is on stage 1 and mainly focuses on manufacturing of security products and equipment. The company has more employees than required, hence, the company operates with staff who have low skills and willing to work for low wages. In this regard the management designs jobs that require little or no skill. Company B outsources 60% of its maintenance activities. However, 80% of its maintenance activities is not planned. The company has no formal maintenance strategy in place. Company B tends to fail in maintenance because they do not have reliable and dependable processes and lack appropriate technology support. Data from the analysis also revealed that the company does not do well in training. OEE is recorded at 30% which shows that there are production stoppages due to breakdowns. The analysis of Case Study B, highlighted that maintenance is considered as an unimportant task.

Company C

Table 4: Company C Maintenance Strategy

Maintenance Strategy for Company C	
Maintenance capacity	35 with outsourced labour
Maintenance facilities	Shortage of equipment
Maintenance technology	70% usage of Condition monitoring
Vertical integration	40% outsourced
Maintenance organization	De- centralised
Maintenance procedures and concepts	PM 40%, TPM 40%, CM 20%
Maintenance scheduling and monitoring	CMMS in use
Manpower	Few professional staff, low training
Maintenance modifications	Few equipment modification
Maintenance performance measurement	Overall Equipment Effectiveness (OEE) at 50%

Company C is on stage 2. The company tries to improve maintenance but has insufficiency capability. The company tries to follow its competitor's maintenance practises. Therefore, hired new managerial and two workers from competing firms. The new manager has restructured the maintenance department. In this regard, best practices from his past employment were implemented and the present maintenance staffs were trained in those practices. Even though the company seems to improve in regard of its production and maintenance performance. According to (Pintelon et al., 2006)

their strategy may work for a short period but limit the possibility of improving the maintenance function on a long term basis, because of following their competitors practices. The company will always remain behind.

Company D

Table 5: Company D Maintenance Strategy

Maintenance Strategy for Company D	
Maintenance capacity	50 with temporary workmen and overtime when required
Maintenance facilities	Spare parts always available
Maintenance technology	40% usage of Condition monitoring technology
Vertical integration	In- house maintenance and 35% outsourced
Maintenance organization	Centralised
Maintenance procedures and concepts	RCM 40%, PDM 35%, PM 25%
Maintenance scheduling and monitoring	CMMS in use
Manpower	Competent personnel, formal training (100 hours/ year)
Maintenance modifications	Less machinery modification
Maintenance performance measurement	Overall Equipment Effectiveness (OEE) at 70%

According to the four stage model Company D is at stage 3. The company integrate service applications in the entire organization and manufacturing success plans. Therefore, considers maintenance as a secondary function. Although the organization has a history on manufacturing advanced and standard products it carries out Preventive, TPM, Condition Based Monitoring and Predictive maintenance policies. These techniques and approaches facilitates and support maintenance management activities, resources and decisions (Simoes et al., 2011). Company D strategies their maintenance activities competently through CMMS practise. CMMS support maintenance management and performance measurement system (Labib, 2004). Maintenance employees are provided with staff training and regular checks on process knowledge every year. Company D carriers out team oriented maintenance. The team uses brainstorming techniques in their commitment to reliability and maintenance management. Consequently, they perform well in other components of maintenance strategy. Case Study D illustrates that organisations at stage 3 handle maintenance more appropriately, however, their focus is into manufacturing and hence their service repairs are costly in contrast to companies at stage 4.

Company E

Table 6: Company E Maintenance Strategy

Maintenance Strategy for Company E	
Maintenance capacity	62 with temporary workers
Maintenance facilities	Spare parts are always available
Maintenance technology	35% usage of Condition monitoring technology
Vertical integration	80% in-house, 20% outsourced
Maintenance organization	De-centralised
Maintenance procedures and concepts	RCM 44%, PDM 25%, PM 31%
Maintenance scheduling and monitoring	CMMS in use
Manpower	Own training centre
Maintenance modifications	Machine modifications
Maintenance performance measurement	Overall Equipment Effectiveness (OEE) at 68%

Company E is on stage 3 and measures value created by maintenance in order to improve. The company is associated with machine modifications on a regular basis. Presently it uses statistical processes control charts in analysing equipment failure. The use of CMMS helps the company to control and manage maintenance task. Apart from carrying out proactive maintenance policies, it has its own training centre. Employees have quick access to training and development programmes, hence, they are easily equipped with skills. Costs on training is reduced. The company uses root cause analysis in order to achieve an effective and efficient maintenance program. In general stage 3 companies does not carry out continuous improvements (Pintelon et al., 2006).

Company F

Table 7: Company F Maintenance Strategy

Maintenance Strategy for Company F	
Maintenance capacity	119 with temporary workmen and overtime when required
Maintenance facilities	Spare parts are always available
Maintenance technology	30% usage of Condition monitoring technology
Vertical integration	20% outsourced
Maintenance organization	Centralised
Maintenance procedures and concepts	RCM 60%, PDM 30%, PM 10%
Maintenance scheduling and monitoring	High and effective usage of Integrated CMMS
Manpower	Skilled staff, high training (160 hours per year)
Maintenance modifications	Continuous improvements

Maintenance Strategy for Company F	
Maintenance performance measurement	Overall Equipment Effectiveness (OEE) at 90%

Company F has a background of many years in the industry and is on stage 4. It has other plants within the country as well as abroad. Some of its spare parts are imported. The company organize its operation and tries to be a step ahead of the competitors, hence it has positively overcome tough competition in its business. Company F organizes its resources in ways which are innovative and can be easily adaptable as the market changes. It nurtures an environment that inspires innovation and integrity. The company offers expert training and development courses to its employees and also develops career guidelines for maintenance staff. The company carries out continuous improvements and has reduced maintenance cost from 50% to 30%. It reflects maintenance as a part of engineering. This qualified them to accomplish World- Class excellence in maintenance and further enabled them to tackle equipment reliability problems earlier. Maintenance contributes to the competitive edge in a business as shown in Company F. It has improved overall equipment effectiveness to 90%. Through training operators work as maintenance personnel.

MAINTENANCE PERFORMANCE ASSESSMENT SCORES FOR THE CASE STUDIED COMPANIES

The six Case Studies (Case Study A - Case Study F) were assessed for maintenance performance and a comparison between the companies was made. The table below shows scores for each benchmarked company. The scores are ranked on a scale of 1 – 5, where 5 is the highest. Table 8 answers section 3 of the questionnaire. Section 3 of the questionnaire asked the surveyed participants to benchmark their maintenance performance on a scale of 1-5, where 1 = uncontrolled, 2 = reactive, 3 = part control, 4 = full control and 5 = fully optimised. The scores of the responses from participants were averaged to the nearest integer value.

Table 8: Maintenance Performance Assessment Scores

Company / Maintenance Performance Factors	A	B	C	D	E	F
Maintenance objectives and key performance factors	2	2	3	4	4	5
Procedures and flowcharts	2	1	3	4	4	5
Asset management and conditioning	1	3	3	4	4	4
Workplace management	3	2	4	4	5	5
Life cycle costing/budgets	3	2	3	3	3	5
Work planning and control	3	1	3	4	4	5
Logistics and spares	2	1	3	3	4	5
Reporting feedback and analysis	3	2	3	3	4	4
Information systems and data management	3	2	3	3	4	4
Continuous improvement and conditioning based monitoring	2	1	3	3	3	5
Manpower, skills and training	2	2	3	4	4	5

Company / Maintenance Performance Factors	A	B	C	D	E	F
Safety and environment	2	3	3	4	3	4

Companies A and B, has no planned maintenance strategy, nor do they practise appropriate procedures in monitoring repairs. Companies C and D are practising maintenance performance measures, however, their procedures are not clearly linked to the business goals. Companies D, E and F were doing well in conducting training. Skills are necessary as they support quality improvement efforts. Company B has low training due to aged employees, this has been proved by the fact that it has the least ranking on information systems. Companies E and F had a record on reporting feedback and analysis. Of the six case studies Company F had some records of TQM. TQM has brought in some changes in the way the company is managed. Right spare parts were provided at the right time in companies E and F. Down time due to the unavailability of spare parts are costly to the company compared to having the part in stock (Wireman, 2010). Companies A, B, C, D and E does not carry out continuous improvement, this shows that these companies fail to reduce maintenance costs as maintenance should be a constantly improving activity.

FOCUS AREAS FOR THE CASE STUDIED COMPANIES

Case studied companies were asked to rank the most important areas of their maintenance activities that would enhance their strategic objectives. Their results are shown in the table below.

Table 9: Ranked Maintenance Factors

Maintenance Factors / Company	A	B	C	D	E	F
Methods and tools for diagnostics	3					
Extended PM-program						
Extended or improved PM-instructions	1		3			
Extended operator maintenance						
Increased number of team-technicians					3	
Extended spare parts storage				2	2	3
Root cause analysis	2		2			
CBM		2				
Training of maintenance personnel		1				2
Training of operators						
Extended service agreements with experts						
Guarantee handling						
Continuous improvement		3	1	3	1	1
Internal knowledge distribution				1		
Other (specify)						

The results show that most companies consider continuous improvement as the most important function followed by root cause analysis and extended spare parts storage. The researchers concluded that the studied companies have a different focus and culture towards maintenance functions.

DISCUSSIONS

The present study was designed to analyze adopted maintenance strategies in six local manufacturing companies. Fredriksson and Larsson (2012) points out that "maintenance strategy should be aligned with manufacturing and business strategies". Consequently, the relevance of a specified maintenance strategy may be influenced by the manufacturing and business requirements. Moreover, an effective maintenance strategy should be suitable for the requirements of an organization. Pintelon et al (2006) suggests that "the practicality of maintenance is realized if a given maintenance strategy can be identified and evaluated". However, companies generally vary in their maintenance strategies by the integration of options observed in the maintenance components. Fredriksson and Larsson (2012) states that "the participation of managers in placing maintenance strategy is crucial because it permits the managers to realize the necessity of manufacturing as a function towards the implementation of a maintenance strategy".

CONCLUSION

In this research, Hayes and Wheelwright's four-stage model (1984) adapted from Pintelon et al., (2006) was applied in analysing adoption of maintenance strategies in six manufacturing companies. The model is appropriate and suitable for the strategic management of the maintenance function. Barnes et al., (2001) emphasise that "it categorize different types of organizations based on their attitude towards their operations. The model proposes the strategic direction for long – term effectiveness.

This study has shown that companies that do not have well planned and defined maintenance strategies, usually look for assistance from external experts to tackle strategic problems involving maintenance. It has further shown that companies in stage 4 realises the potential of innovative applications and technologies and attempt to find information before their implications are clearly visible.

The conclusions drawn from the present study shows that equipment maintenance and reliability management are importantly associated with an organizations competitiveness and must be given adequate attention in the organizations strategic planning (Madu, 2000). Therefore, maintenance can allow to increase the competitive edge of an organisation if managed properly.

LIMITATIONS

Financial analysis or benefit gained from the implementation of the maintenance strategies was not done. It was difficult for the research team to get the financial data. Future research work can focus on statistical analysis on the impact of maintenance strategies on production and financial performance.

APPENDIX A

Questionnaire on maintenance strategies

Evaluation of Maintenance Strategies Found in Local Manufacturing Industries

The purpose of this study is to evaluate maintenance strategies found in local manufacturing industries. This questionnaire will gather information on how local manufacturing industries implement their maintenance strategies.

1. Kindly indicate by inserting X against the maintenance strategy adopted by your company:

Maintenance strategy	**Adopted**
Corrective maintenance-done after a detection of an anomaly	
Preventive maintenance- done at predetermined intervals	
Risk based maintenance-integrates analysis, measurement and periodic tests	
Condition based maintenance- performance monitoring	
Re-design- carrying out equipment modifications	

2. Maintenance strategy is made up of (a) structural decision elements and (b) infrastructural decision elements. Kindly indicate how your company deploys resources in the following elements:

(a)

Structural decision elements	**Description**	**Indicate your response**
Maintenance capacity	Capacity in terms of workforce, supervisory and management staff. Shift patterns of work force, temporary hiring of workforce	
Maintenance facilities	Tools, equipment, spares, workforce specialization	
Maintenance technology	Predictive maintenance or condition monitoring technology, expert systems	
Vertical integration	In-house maintenance vs outsourcing and relationship with suppliers	

(b)

Infrastructure decision elements	**Description**	**Indicate your response**

Maintenance organization	Organization structure (centralized, decentralized or mixed), responsibilities	
Maintenance policy and concepts	Policies like corrective, preventive and predictive maintenance. Concepts like total productive maintenance (TPM), reliability centered maintenance (RCM), PDM-predictive maintenance	
Maintenance planning and control systems	Maintenance activity planning, scheduling. Control of spares, costs, etc. Computerized maintenance management systems, CMMS	
Human resources	Recruitment policies, training and development of workforce and staff. Culture and management style	
Maintenance modifications	Maintenance modifications, equipment design improvements, new equipment installations and new machine design support	
Maintenance performance measurement and reward systems	Performance recognition, reporting and reward systems, Overall equipment effectiveness (OEE) and balanced score card (BSC)	

3. Benchmarking focusses on processes and evaluates their relative performance. On a scale of 1 – 5 indicate how your company rates the following benchmarking indices:

1 = uncontrolled

2 = reactive

3 = part control

4 = full control

5 = fully optimized

Benchmarking item	**Rating--**Kindly indicate your rating by inserting a number of your

	choice from 1 to 5 as guided by the scale above
Management objectives and key performance indicators	
Procedures and Flowcharts	
Asset management and conditioning	
Workplace management	
Life Cycle Costing / Budgets	
Work planning and control	
Logistics and spares	
Reporting feedback and analysis	
Information systems and data management	
Continuous improvement and Condition based monitoring	
Manpower, skills and training	
Safety and environment	

4. Please rank the **three** areas that you consider most important for the maintenance organization to focus on in-order to achieve the goals:
   1 = most important
   2 = second most important
   3 = third most important

Leave the other areas blank.

Methods and tools for diagnostics	
Extended PM-program	
Extended or improved PM-instructions	
Extended operator maintenance	
Increased number of team-technicians	
Extended spare parts storage	
Root cause analysis	

CBM	
Training of maintenance personnel	
Training of operators	
Extended service agreements with experts	
Guarantee handling	
Continuous improvement	
Internal knowledge distribution	
Other (specify)	

5. If you have any other remarks or comments on the subject of maintenance strategy and improvement, please specify here----------
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