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An Approach for Improving Maintenance Management System in the Nigerian Construction Industry

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ABSTRACT:
Noticeably a commendable metamorphosis has occurred recently in the maintenance management ofphysical assets and productive systems, a large component of this change is an effort to improve capabilities, while reducing overall running costs. To accomplish these goals, the construction industry must improve both the quality of work done and the reliability of their production equipment. The implantation of an innovative maintenance management approach, applied in the proper environment, can provide an effective set of processes to drastically improve effectiveness through more reliable production equipment. The need for optimal preventive maintenance using,the just-in- time (JIT) and total quality-management (TQM) strategies brought the emergence of total productive maintenance (TPM) method. However, the construction industry in Nigeria currently does not have a reliable, repeatable methodology for machinery maintenance activities.Hence, the intent of this work is to suggest and find means by which constructionindustry in Nigeria can adopt and implement; the emerging TPM as an effective maintenance management approach for improving its performance and productivity.

Keywords: construction, maintenance, management system, operating sustainability, facility services

Explanation of some terms

- Condition-based Maintenance: The kind of maintenance carried out according to the need indicated by condition monitoring[12];
- Cost-effective maintenance: The measure of how much of the considered maintenance policy is economically beneficial in the long run whereby two situations (before and after maintenance improvement) is compared with the use of a dimension less ratio. [8];
- Maintenance: 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. [13];
- Maintenance concept: The set of various maintenance interventions (e.g. corrective, preventive, condition-based, etc.) and the general structure with which these interventions are governed. [9];
- Overall Equipment Effectiveness (OEE): A tool to manage and improve the production/ manufacturing process. [11]; and
- Technology: A combination of management, financial, engineering, building and other practices applied to physical assets in pursuit of economic life cycle costs. [12], [15];
- Just-in-Time (JIT): which was first implemented in the Toyota Manufacturing Company. JIT is a technique for reducing wastage through procedures that establish good communications throughout the production process to ensure that all resources are used optimally. In other words, 'let only the system that needs parts get them, and only in the quantity needed' i.e. lean management, [1], [2] and [14].
- Asset management: Recording data equipment and property including maintenance activities, specifications, purchase date, expected lifetime, warranty information, service contracts, service history, spare-parts and anything, that might be of help to maintenance or maintenance workers [10];

- Total quality management (TQM): a technique use in motivating people, focuses on people and machine,putting yourself in your customer's place; and
- Total productiveMaintenance (TPM): This is a recently-introduced maintenance strategy forplant and equipment usually involves a change in themind-set of personnel towards their jobresponsibilities. It requires commitment to theprogramme by members of the upper levelmanagement team as well as empowering employeesto initiate corrective actions for defaulting aspects ofthe system or process under their purview[8], [14].

I. INTRODUCTION

Monier Construction Company (MCC) is one of the leading Nigerian construction companiesbased in Port Harcourt in Rivers Stare Nigeria, offering holistic services covering the planning, design, engineering, construction, operation and maintenance of buildings, infrastructure, transportation terminals, manufacturing facilities and industry projects in Nigeria. Acompany's history of success together with the shared values that define the culture and way of working should give various clients the confidence to trust with most demanding projects.

1. Operating sustainability: The Companyneed totallyadhere to the highest standards for quality and safety. To maintain excellence in construction, it is equally required of the company to strive to stay at the forefront of the construction industry, continuously building on robust experience and strong technical expertise through development and innovation for the creation of long-term value. Furthermore, the company should be leading in constructing according to environment protection standards, with proven capacity to construct high performance green buildings built to comply with the Leadership in Energy and Environmental Design (LEED) requirement.

2. Industrial construction:Monier Construction Company (MCC) essentially has to successfully contribute to enabling the growth of industries through the provision of comprehensive civil works including design, engineering and procurement, steel works as well as mechanical and electrical works, for the construction of plants, factories, auxiliary buildings, oil and gas installations and power stations. Offering clients decisive advantages based on vast Nigeria-specific knowhow and technical expertise, which presently is conspicuously absent in its operations.

3. Facility services: Monier Construction Company (MCC) need expectedly offer quality operation and maintenance services to provide clients preventive and proactive facility services. This multiservice operational structure intended to simplify the often complex process of asset maintenance, with the capacity to handle operation of building and office infrastructure and refurbish facilities as required – to preserve the sustained availability and high value of assets. Furthermore, maintenance of equipment, optimization of utilities and related technical solutions to improve resource management and reduce operating costs, which in essence is lacking.

1.1 Background to the problem

The technology of maintenance is about finding and applying cost-effective ways of avoiding or overcoming performance deterioration. Failure-management techniques include predictive and preventive actions, failure-finding, run-to-failure and changes to the design of the physical asset or the way it is operated. Each category includes ahost of options, some of which are far more effective than others. Maintenance staffs not only need to be aware of what these options are, but they also have to decide which are appropriate to their circumstances. Making a wise choice should improvethe asset's performance, as well as reduce overall costs, and making a wrong choice could create new problems while existing ones may worsen. Failures usually attract attention because they can adversely affect output, safety, and environmental health, quality of end product, customer service, competitiveness and unit costs. The severity and frequency with which failure leads to these consequences dictate which failure-management technique is worth applying. Therefore, the mission statement should acknowledge the key role of 'consequence avoidance' in maintenance. The policy should be effective in the use of resources (i.e. people, materials, spares, tools, etc.). Hence, the cost of maintenance depends not only on the maintenance staff, but also on the designers and operators of the considered production system. In the present high-stress, turbulent business-environment, well-run organizations strive continually to enhance their capabilities to create excellent value for the

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customers by improving the cost effectiveness of the operations. Maintenance is thus a vital support function in business, especially as increasingly large investments are being required in physical assets,[7].

II. LITERATURE REVIEW

Maintenance Management System provides a comprehensive, life cycle approach, to equipment management that minimizes equipment failures, production defects, and accidents. It involves everyone in the organization, from top level management to production mechanics, and production support groups to outside suppliers. The objective is to continuously improve the availability and prevent the degradation of equipment to achieve maximum effectiveness. These objectives require strong management support as well as continuous use of work teams and small group activities to achieve incremental improvements. The system is not a radically new idea; it is simply the next step in the evolution of good maintenance practices, [3], [4].

Equipment maintenance has matured from its early approach of 'breakdown maintenance'. In the beginning, the primary function of maintenance was to get the equipment back up and running, after it had broken down, where the attitude of the equipment operators was one of "I run it, you fix it". The next phase of the maintenance history was the implementation of 'preventive maintenance'. This approach to maintenance was based on the belief that if you occasionally stopped the equipment and performed regularly scheduled maintenance, the catastrophic breakdowns could be avoided. The next generation of maintenance brings us to TPM. In TPM, maintenance is recognized as a valuable resource. "The maintenance organization now has a role in making the business more profitable and the constructing system more competitive by continuouslyimproving the capability of the equipment, as well as making the practice of maintenance more efficient"[5], [6].

2.1 Maintenance management systemconcepts

Different sources provide several different descriptions of what makes up a good and productive maintenance management system. Some list five different concepts, others list up to seven different concepts that fall under the umbrella of the maintenance management system. Rather than try to decide which the correct quantity is, the concepts will simply be collected into three different groupings of these concepts: Autonomous Maintenance, Planned Maintenance, and Maintenance Reduction.[4], [7]

2.1.1 Autonomous maintenance

The central idea of autonomous maintenance is using the equipment operators to perform some of the routine maintenance tasks. These tasks include the daily cleaning, inspecting, tightening, and lubricating that the equipment requires. Since the operators are more familiar with their equipment than anybody else, they are able to quickly notice any anomalies. The training required to make autonomous maintenance effective comes in several forms: the maintenance staff trains the operators on how to properly clean and lubricate the equipment, and special safety awareness training is provided to address the new tasks performed by the equipment operators. Implementing autonomous maintenance often includes the use of 'visual controls'. Visual control is an approach used to minimize the training required to learn new tasks, as well as to simplify inspection tasks. The equipment is marked and labeled to make identification of normal vs. abnormal conditions easier to identify. The equipment operators are also expected to collect daily information on the health of their equipment: downtime (planned and unplanned), product quality, any maintenance that was performed (tightening loose bolts, adding coolant fluid, etc.). This information is useful to both the operator and the maintenance staff to identify any signs that the equipment is beginning to degrade, and may be in need of more significant maintenance.

2.1.2 Planned maintenance

Planned maintenance activities (also known as 'preventive maintenance') are scheduled to repair equipment and replace components before they breakdown. This requires the production schedule to accommodate planned downtime to perform equipment repairs, and allowingthese repairs to be treated as a priority on par with running the equipment to produce parts. The prevailing theory is that as the planned maintenance goes up, the unplanned maintenance (breakdowns) goes down, and the total maintenance costs go down as a result.

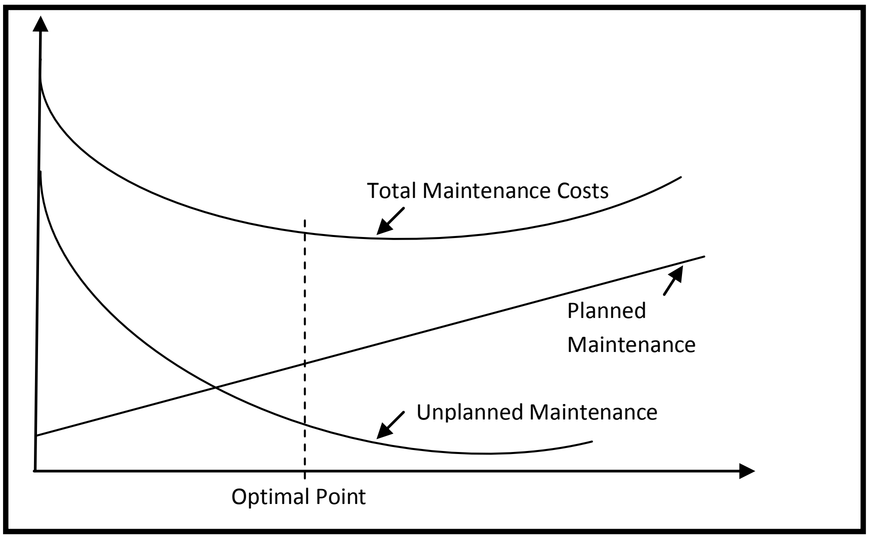

Figure 1: Trade-off between Planned and Unplanned Maintenance.

Source: [5]

However, most of the management systems that are available and in use have failed to collect the necessary data to prove this theory. Even if this trade-off is not always achievable, it is easy to see that the equipment will likely receive better care than it was prior to implementing management approach. The maintenance departments, as a team, should determine the proper amount of planned maintenance, based on the condition of the equipment and the type of activity to carry out. Performing excessive amounts of maintenance can be as costly as not performing enough maintenance; their needs to be a balance point determined by careful analysis of the equipment. Performing planned maintenance, in the proper amounts, requires an in-depth understanding of the construction equipment to be used, down to the equipment component level. This understanding need to start with the work produced and their critical features, and flow down through the equipment, the equipment's processes, to the process parameters. Figure 2 below show a graphic example of how the critical top level requirements of a product can be traced down to the manufacturing process parameters.

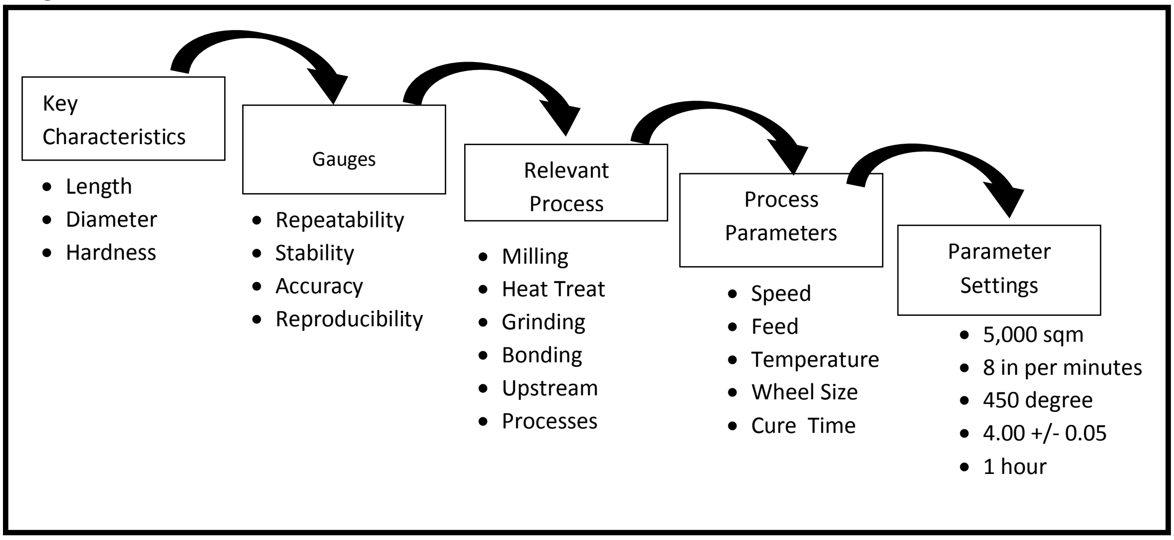

Figure 2: Key Characteristic to Process Parameters

Source: [5]

Once the construction and maintenance team has identified what they believe to be the critical process parameters, they need to validate these, as well as determine the proper parameter settings. Planned maintenance uses data from process capability and machine capability studiesto determine acceptable performance levels. The process capability studies evaluate theequipment's ability to manufacture consistently high quality parts. The machinecapability study analyzes the equipment's ability to perform a specific set of operations, and compares the results to industry standards. Both of these studies, when performed ona periodic basis, can provide indicators that the equipment's performance is going downhill,and that it will start producing bad products, or have a breakdown, in the near future.

2.1.3 Maintenance reduction

The basic maintenance management concept is made up of two parts, equipment design and predictive maintenance, which are focused on reducing the overall amount of maintenance that is required. By working with equipment suppliers, the knowledge that is gained from maintainingequipment can be incorporated into the next generation of equipment designs. This 'Design for Maintenance' approach results in equipment that is easier to maintain and can be immediately supported with autonomous maintenance. The equipment manufacturer can even include the visual control markings and labels that the customer currently uses for cleaning, inspecting, and lubricating. This communication between supplier and customer can also be used to establish equipment performance criteria. Both the supplier and the customer should be able to achieve the same results from their machine capability studies, and this can serve as an equipment acceptance test. Also, the equipment supplier may be able to provide data on their components that will help to determine the required frequency of inspections and planned maintenance.

The other method of reducing the amount of required maintenance is to perform special equipment analysis to collect data that can be used to predict equipment failures. This type of analysis includes thermography, ultrasound, and vibration analysis, which allows a technician to gather information on what is happening inside the equipment. Thermography is used to detect equipment 'hot spots', where the excessive heat may be related to bearing wear, poor lubrication, or plugged coolant lines. Ultrasound analysis is used to detect minute cracks in the equipment that are invisible to the human eye for early enough repairs.Vibration analysis is used to detect unusual equipment vibration (both in magnitude and frequency). These types of equipment analysis can be performed on a periodic basis, the frequency of which can be fine tuned as historical data starts to show trends.

III. EQUIPMENT EFFECTIVENESS

"When the term 'equipment effectiveness' is used, it often refers to the equipment availability or up-time, the percentage of time it is up and operating. But the overall or true effectiveness of equipment also depends upon its performance and its rate of quality". One of the primary goals of an innovative management system is to maximize equipment effectiveness by reducing the waste in the manufacturing process. The three factors that determine equipment effectiveness: equipment availability, performance efficiency, and quality rate are also used to calculate the equipment's Overall Equipment Effectiveness (OEE) measure which is described later in the strategy Metrics section.

3.1 Equipment Availability

A well functioning construction system will have its equipment available for use whenever it is needed. This doesn't mean that the equipment must always be available. For example, in a synchronized production system there is little benefit to having equipment up and running when the products aren't necessary. This simply builds up the system's inventory. However, if there is a need to increase the production rate, the equipment must be capable of satisfying the increased demand. The equipment management program must strike a balance between the costs of keeping the potential utilization of the equipment high, versus the cost storing excessive inventory to avoid missing a sales opportunity. The equipment availability is affected by both scheduled and unscheduled downtime. In a well functioning system the unplanned downtime is minimized, while the planned downtime is optimized; based on the amount of inventory in the system and the equipment's ability to change working rates. The in-process inventory can often be used to satisfy the downstream demands while the equipment is temporarily shut down to perform maintenance tasks. Determining the proper amount of inventory becomes a function of how often the equipment is down for both scheduled and unscheduled repairs. The most common cause of lost equipment availability is unexpected breakdowns. These failures affect the maintenance staff (which must scramble to get the equipment running) and the equipment operator (who often has to wait for the equipment to be repaired to continue working). Keeping back-up systems available is one way to minimize the effect of lost equipment availability.

3.2Performance Efficiency

Equipment efficiency is a commonly used to metric when evaluating a productionsystem. The efficiency is typically maximized by running the equipment at its highest speed, for as long as possible, to increase the product output. The efficiency is reduced by time spent with the equipment idling (waiting for parts to load), time lost due to minor stops (to make small adjustments to the equipment), and lower output from running the equipment at irregular speed. These efficiency losses can be the result of low operator skill, worn equipment, or poorly designed systems when it relates to construction activity. However, just measuring the equipment's efficiency can lead to poor decision making, because the system may not benefit from traditional goal of 100% efficiency. The important criterion is how many jobs should the equipment be accomplishing, not how many it can show off if run at a break-neck pace. The target efficiency need of equipment is to consider how the equipment is designed to work, and its working capacity. When the equipment is up and running, it should be capable of being run at its designed speed, but when not needed, shut the equipment down and use this time to perform other tasks. This occasional downtime can be very usefulfor performing autonomous maintenance, planned maintenance, and equipment analysis.

3. 3 Quality rate

If the equipment is available and operating at its designed speed, but is producing poor quality outputs, what has really been accomplished? The purpose of the manufacturing system is not to run equipment just to keep busy and watch machines operate; the purpose is to make useful products. If the equipment is worn to the point where it can no longer produce acceptable parts, the best thing to do is shut it down to conserve the energy and raw materials, and repair it. Quality losses also include the lost time, effort, and outputs that result from long warm up periods or waiting for other process parameters to stabilize. For example, the time lost and parts scrapped while waiting for an injection molding machine to heat up should be considered part of the equipment's quality rate. The effort to improve the quality rate needs to be linked back to the critical product requirements. There is little benefit from producing parts that are perfect in almost every feature, except for the critical feature that matters most to the customer. The concept of key characteristics is useful for aligning the critical product features with the responsible equipment parameters, the parameters that need to be improved in order to have the maximum benefit to the overall system are also the parameters and features that should be measured when determining the quality rate of equipment in production.

IV. MANAGEMENT FEASIBILITY

Practically every subject on the maintenance management system will have a section dedicated to discussing the benefits, some of which list examples of companies that have achieved monumental gains. The most commonly listed benefits are as follows:

- Reduced Variability (of production parts and production schedules): This results fromequipment that has greater accuracy and repeatability, and from less unexpected breakdowns;
- Increased Productivity: Since the equipment is breaking down less frequently, themachines and operators are not waiting around while it gets repaired. Also, there ismore output due to less total downtime, reduced set-up times, and fewer equipment adjustments;
- Reduced Maintenance Costs: With less 'fire-fighting' required, the maintenance staffcan level load the maintenance work orders. Also, the equipment is repaired on when need arise, rather than a just-in-case basis; hence reducing unnecessary replacement of components;
- Reduced Inventory: The system does not need to store as much inprocessinventory to provide a protective cushion to protect against starving thedownstream process when equipment breaks down incessantly. Also, the equipmentspare parts inventory can be reduced, based on more accurate estimates of component replacement requirements; and
- Improved Safety: Operators are more familiar with their equipment due to the dailyinspections and minor maintenance performed. Further, reducing breakdowns thatrequire removing jammed parts, broken chains etc.

4.1 Managementmetrics

As previous, there are data collection requirements that are a prerequisite to even starting a maintenance program. Once the organization has decided that a particular methodologyis appropriate for their current situation, there are additional data collection requirements inherent for usage in the process.

4.1.1 Overall Equipment Effectiveness

The concept of overall equipment effectiveness (OEE) is included in nearly all innovative productive maintenance literature, and described in detail for those interested in learning how it is measured and used. OEE is calculated by multiplying the equipment availability, performance efficiency, and quality rate; as previously described. The data required to determine these values is: scheduled downtime, unscheduled downtime, and output (both good and bad parts); which is collected by the equipment operators on a daily basis. Implementing control charts on the equipment availability, performance efficiency, and quality rate provides aggregate data that is useful for tracking any changes in equipment performance. However, these control charts should have pre-defined thresholdsto determine when more detailed data collection is required, so that the necessary changes can be made prior to catastrophic failure. Determining these thresholds requires firstcollecting a history of the OEE data, along with a history of more detailed data, where undesirable events and their causes can be identified.

4.2 Processimplementation methodology

The explanation here provides some critical issues overview of maintenance management implementation process that requires graveconsideration. The chart in Figure 4 belowdepicts the principal activities that make up the majority of the implementation effort. This implementation plan uses the concepts that have been described previously, and should be given approximately 5 years to be completed.The following is a brief description of each of the implementation activities, [15].

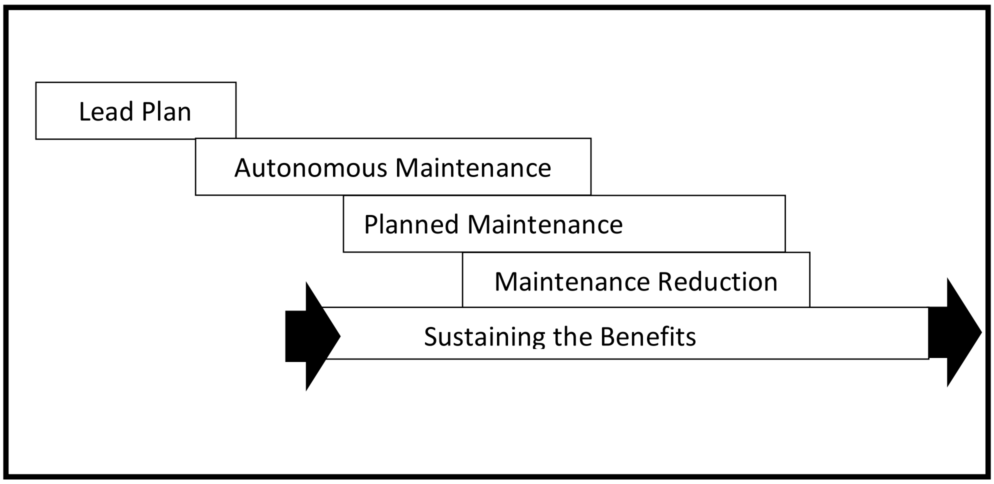

Figure 4: Process Implementation Activities

Source: [5]

4.2.1 Lead Plan:

The maintenance team, along with work force involved in the construction operation and maintenance management, and union representatives determines the scope/focus of the maintenance program. The selected equipment and their implementation sequence are determined at this point. Baseline performance data is collected and the program's goals are established.

4.2.2 Autonomous Maintenance:

The maintenance team is trained in the methods and tools of selected methodology and visual controls. The equipment operators assume responsibility for cleaning and inspecting their equipment and performing basic maintenance tasks. The maintenance staff trains the operators on how to perform the routine maintenance, and all are involved in developing safety procedures. The equipment operators start collecting data to determine equipment performance.

4.2.3 Planned Maintenance:

The maintenance staff collects and analyzes data to determine usage/need based maintenance requirements. A system for tracking equipment performance metrics and maintenance activities is created (if one is not currently available). Also, the maintenance schedules are integrated into the production schedule to avoid schedule conflicts.

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4.2.4 Maintenance Reduction:

The data that has been collected and the lessons learned from the process implementation are shared with equipment suppliers. This 'Design for Maintenance' knowledge is incorporated into the next generation of equipment designs. The maintenance staff also develops plans and schedules for performing periodic equipment analysis (thermography, oil analysis, etc.). This analysis data is also fed into the maintenance database to develop accurate estimates of equipment performance and repair requirements. These estimates are used to develop spare part inventory policies and proactive replacement schedules.

4.2.5 Sustaining the Benefits:

The new maintenance practices are incorporated into the organization's standard operating procedures. These new methods and data collection activities should be integrated with the other elements of the production system to avoid redundant or conflicting requirements. The new equipment management methods should also be continuously improved tosimplify the tasks and minimize the effort required to sustain the innovative program.

V. IMPLEMENTATION PLAN FOR PROCESS IMPROVEMENT

The implementation planbelow provides a more detailed descriptive pattern of what is required to do in a small collection of construction work cells. Developing an effective implementation plan should be viewed as an iterative process where the plans are updated as the team learns from using the plans. This plan provides a step-by-step guide to introducing the process into the workplace. It uses a staggered scheduling approach, which starts with the highest priority equipment, as determined by a cross functional team. The prioritization is based on equipment safety, reliability, quality, etc. Once the first implementation team is up and running, the next highest priority equipment will be targeted. The plan also uses the concept of 'natural work groups' for forming planning and implementation teams. The activities in this plan borrow heavily from the concepts of Total Quality Management (TQM) and Lean Manufacturing, giving rise to Total Productive Maintenance (TPM).

The implementation plan was prepared forMonier Construction Company (MCC) as case study; however the scope can be expanded to include other construction companiesthat are also striving in the industry. If the scope of the implementation is to be expanded, the basic change required is that a higher level management support team is required. This higher level team would need to oversee the implementation in the various areas to assure consistency.

2.2 Goals

Goals for the implementation plan:

- Increase the amount of time that the production equipment is available for use;
- Reduce the amount of hardware variability in the parts produced;
- Reduce the number of accidents in the workplace;
- Encourage production mechanic ownership of, and responsibility for, their equipment;
- Establish metrics to allow data driven decisions;
- Provide factory production mechanic/equipment operator (user) ownership of this plan;
- Foster management support of this plan, and JIT,TQM and TPM in general;
- Raise the level of maintenance support for the equipment;
- Integrate manufacturing initiatives (JIT, TQM, TPM, good Housekeepingand Safety);
- Improve the orderliness of the workshop;
- Avoid the elimination of jobs; and
- Minimize the negative impact of change on the affected individuals.

Task of the implementation effort will be assisted by providing this basicinformation:

i. Goals of each task;
ii. Training required;
iii. Data collection requirement;
iv. Problem solving tools utilized;
v. Team membership requirements;
vi. Team leader responsibilities (including what organization they should be from);
vii. Activities to be performed;
viii. Time required to perform activities and
ix. Role of management.

The maintenance managers in the construction industry must move away from traditional reactive maintenance procedures to implementing more proactive maintenance processes. By better planning of maintenance schedules, in doing so, less energy and effort are wasted, improved productivity occurs and greater financial surpluses are achieved.

VI. CONCLUSION

The recommended innovative and valid world class approach to equipment management that involves everyone, working to increase equipment effectiveness includes the following but not limited to; just-in time (JIT), total quality management (TQM) and its emergent;Total Productive Maintenance (TPM). Successful implementation of this approach requires shared responsibilities, total employee involvement, and normal work groups. An approach often implemented as a stand alone improvement activity. However, it is my belief that it should be done in concert with the other elements of a world systems. The synergy of the world class totaling and all embracing concepts such as inventory reduction, hardware variability control, and cycle time reduction, can provide benefits that are greater than the sum of their parts. "Construction equipment is like the goose that lays the golden eggs, if you want to keep getting golden eggs; you need to take care of the goose!"

The willingness of employees within an organization to accept "change" for the better is an essential prerequisite for successfully implementing the valid innovation. The process can only succeed in an organization that is committed to provide the necessary training and time to monitor the success or failure of the ensuing improvement initiatives.The completeimplementation and achieving sustainability in the construction industry in Nigeria, using the proposed approach, there should be a recalibration of what is expected in existing organizations and this should be self-auditing and benchmarkingagainst world-class industries with similar trade lines.

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