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Studying The Factors Affecting Advanced Mechanical Maintenance Practice

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I. Introduction

The term maintenance strategy is generally viewed from the perspective of maintenance policies and concepts. For instance, it is defined in terms of reactive or breakdown maintenance, preventive and predictive maintenance (Cooke, 2003, pp. 239–249). Maintenance though closely related to manufacturing is a business function of its own. Its business is to provide dependable service to manufacturing. Hence, maintenance strategy can be defined at a functional hierarchy level. It can be defined as coherent, unifying and integrative pattern of decisions in different maintenance strategy elements in congruence with manufacturing, corporate and business level strategies; determines and reveals the organizational purpose; defines the nature of economic and non-economic contributions it intends to make to the organization as a whole.

In order to achieve world-class performance, more and more companies are undertaking efforts to improve quality and productivity and reduce costs. For more and more companies, part of this effort has included an examination of the activities of the maintenance function. Effective maintenance is critical to many operations. It extends equipment life, improves equipment availability and retains equipment in proper condition. Conversely, poorly maintained equipment may lead to more frequent equipment failures, poor utilization of equipment and delayed production schedules. Misaligned or malfunctioning equipment may result in scrap or products of questionable quality. Finally, poor maintenance may mean more frequent equipment replacement because of shorter life.

II. Evolution of Maintenance Strategie

The approach to maintenance has changed dramatically over the last century (Blischke & Murthy, 2000, pp. 25-63). Up to about 1940, maintenance was considered an unavoidable cost and the only maintenance was CM. Whenever an equipment failure occurred, a specialised maintenance workforce was called on to return the system to operation. Maintenance was neither incorporated into the design of the system, nor was the impact of maintenance on system and business performance duly recognised. The evolution of operations research (OR) from its origin and applications during the Second World War to its subsequent use in industry led to the widespread use of PM. Since the 1950s, OR models for maintenance have appeared at an ever-increasing pace. These models deal with the effect of different maintenance policies and optimal selection of the parameters of the policies. The impact of maintenance actions on the business performance is not addressed. In the 1970s, a more integrated approach to maintenance evolved in both the government and private sectors. New costly defence acquisitions by the US government required a life cycle costing approach, with maintenance cost being a significant component. The close linkage between reliability (R) and maintainability (M) was recognised. The term “R&M” became more widely used in defence-related systems. This concept was also adopted by manufacturers and operators of civilian aircraft through the methodology of reliability centred maintenance (RCM) in the USA. In the RCM approach (Moubray, 1991, pp. 42-57), maintenance is carried out at the component level and the maintenance effort for a component is a function of the reliability of the component and the consequence of its failure under normal operation. The approach uses failure mode effects analysis (FMEA) and to a large extent is qualitative. At the same time, the Japanese evolved the concept of total productive maintenance (TPM) in the context of manufacturing (Tajiri & Gotoh, 1992, pp. 47-74). Here, maintenance is viewed in terms of its impact on the manufacturing through its effect on equipment availability, production rate and output quality.

III. Reactive Maintenance

Reactive maintenance may be described as a fire-fighting approach to maintenance. Equipment is allowed to run until failure. Then the failed equipment is repaired or replaced (Paz & Leigh, 1994, pp. 47–69). Under reactive maintenance, temporary repairs may be made in order to return equipment to operation, with permanent repairs put off until a later time (Gallimore & Penlesky, 1988, pp. 16–22).

Reactive maintenance allows a plant to minimize the amount maintenance manpower and money spent to keep equipment running [5]. However, the disadvantages of this approach include unpredictable and fluctuating production capacity, higher levels of out-of-tolerance and scrap output, and increased overall maintenance costs to repair catastrophic failures (Vanzile & Otis, 1992, pp. 1575–1584).

IV. Proactive Maintenance

Proactive maintenance is a strategy for maintenance whereby breakdowns are avoided through activities that monitor equipment deterioration and undertake minor repairs to restore equipment to proper condition. These activities, including preventive and predictive maintenance, reduce the probability of unexpected equipment failures.

V. Preventive Maintenance

Preventive maintenance is often referred to as use-based maintenance. It is comprised of maintenance activities that are undertaken after a specified period of time or amount of machine use (Gits, 1992, pp. 217–226). This type of maintenance relies on the estimated probability that the equipment will fail in the specified interval. The work undertaken may include equipment lubrication, parts replacement, cleaning and adjustment. Production equipment may also be inspected for signs of deterioration during preventive maintenance work.

The benefits of preventive maintenance are reduced probability of equipment breakdowns and extension of equipment life. The disadvantage of preventive maintenance is the need to interrupt production at scheduled intervals to perform the work.

VI. Predictive Maintenance

Predictive maintenance is often referred to as condition-based maintenance. Specifically, maintenance is initiated in response to a specific equipment condition (Vanzile & Otis, 1992, pp. 1575–1584). Under predictive maintenance, diagnostic equipment is used to measure the physical condition of equipment such as temperature, vibration, noise, lubrication and corrosion (Eade, 1997, pp. 68–72). When one of these indicators reaches a specified level, work is undertaken to restore the equipment to proper condition. This means that equipment is taken out of service only when direct evidence exists that deterioration has taken place.

Predictive maintenance is premised on the same principle as preventive maintenance although it employs a different criterion for determining the need for specific maintenance activities. As with preventive maintenance, predictive maintenance reduces the probability of equipment breakdowns. The additional benefit comes from the need to perform maintenance only when the need is imminent, not after the passage of a specified period of time.

VII. Total Productive Maintenance

The literature has revealed that the manufacturing organizations worldwide are facing many challenges to achieve successful operation in today's competitive environment. Modem manufacturing requires that to be successful, organizations must be supported by both effective and efficient maintenance practices and procedures. Over the past two decades, manufacturing organizations have used different approaches to improve maintenance effectiveness (Roup, 1999, pp.32-35). One approach to improving the performance of maintenance activities is to implement and develop a TPM strategy. The TPM implementation methodology provides organizations with a guide to fundamentally transform their shop-floor by integrating culture, process, and technology (Moore, 1997, pp.88-90).

PM is considered to be Japan's answer to US style productive maintenance (Wal & Lynn, 2002, pp.359-66). TPM has been widely recognized as a strategic weapon for improving manufacturing performance by enhancing the effectiveness of production facilities (Dossenbach, 2006, pp.29-32). TPM has been accepted as the most promising strategy for improving maintenance performance in order to succeed in a highly demanding market arena. TPM is the proven manufacturing strategy that has been successfully employed globally for the last three decades, for achieving the organizational objectives of achieving core competence in the competitive environment. TPM is a highly influential technique that is in the core of “operations management” and deserves immediate attention by organizations across the globe (Voss, 2005, pp.1223-7).

TPM is a methodology originating from Japan to support its lean manufacturing system, since dependable and effective equipment are essential pre-requisite for implementing Lean manufacturing initiatives in the organizations. TPM is a production-driven improvement methodology that is designed to optimize equipment reliability and ensure efficient management of plant assets. TPM is a change philosophy, which has contributed significantly towards realization of significant improvements in the manufacturing organizations in the West and Japan. TPM has been depicted as a manufacturing strategy comprising of following steps (Bamber et al., 1999, pp.162-81):

- Maximizing equipment effectiveness through optimization of equipment availability, performance, efficiency and product quality;
- Establishing a preventive maintenance strategy for the entire life cycle of equipment;
- Covering all departments such as planning, user and maintenance departments;
- Involving all staff members from top management to shop-floor workers; and
- Promoting improved maintenance through small-group autonomous activities.

TPM describes a synergistic relationship among all organizational functions, but particularly between production and maintenance, for the continuous improvement of product quality, operational efficiency, productivity and safety. It also helps to maintain the current plant and equipment at its highest productive level through the cooperation of all functional areas of an organization.

VIII. Reliability Centered Maintenance

Reliability centered approach was founded in the 1960s and initially oriented towards aircraft maintenance. It is now only in the past ten years or so that this concept has started coming to the industry. It directs maintenance efforts at those parts and units where reliability is critical. A total of five papers have been published in the last few years. Gabbar et al. (2003, pp.449-58) present an improved RCM (automated environment) process as integrated with CMMS. The major components of the enhanced RCM process are identified and a prototype as integrated with the various modules of the adopted CMMS is implemented. Wessels (2003, pp.412-6) proposes a cost optimized scheduled maintenance interval that uses costs as the constraint and overcomes quantitative complexity by use of computer/software technology. This interval enables an organization to implement a comprehensive RCM program effectively.

Eisinger and Rakowsky (2001, pp.159-64) discuss a probabilistic approach in the modeling of uncertainties in RCM. They conclude by saying that these uncertainties in the decision making of RCM might be unacceptable in many practical applications, leading to non-optimum maintenance strategies.

IX. Computerized Maintenance Management Sy tem

Computerized maintenance management systems are common in today's industries. Their use has brought a large number of benefits which include increased productivity, reduced costs, and effective utilization of the labor force (Bagadia, 1987). These computerized maintenance management systems were initially used on mainframe computers but this was shifted later to micro-computers (Allman & Bottom, 1985). A large variety of such systems is now commercially available.

Corder gives an insight into the scope of modern maintenance management, "maintenance management is very wide indeed, since almost all current engineering, management and accounting practices have some relevance to the subject" [7]. Greater demands are being imposed on the maintenance manager in order to improve the standard of maintenance and efficiency of work while at the same time reducing maintenance operational costs.

Chapman states that CMMS software was seen first around 1976 (Chapman, 1993). Today it is widely used in manufacturing plants all over the world. Maintenance optimisation is greatly facilitated when companies adopt a World Class Manufacturing/Maintenance (WCM) philosophy or management strategy in conjunction with CMMS implementation. There are many factors, which influence management on installing CMMS software and using it within their plants.

The variety of tasks associated with the organisation of maintenance management lends itself to the utilisation of computer systems. It is in this area including planning, organisation and administration of maintenance management that Computer Maintenance Management Systems (CMMSs) have proved to be very beneficial. The top five problems encountered by maintenance managers and suggest that CMMS is the solution to these problems. The problems are outlined as follows:

1. Little or no support from management to implement world class maintenance practices, CMMS reports can highlight the levels of downtime and reduce costs.
2. Inventory problems, the need to reduce spares and still have parts on hand. Control of spares modules is part of most of the modern CMMS packages.
3. The problems associated with maintenance personnel excelling at some jobs and lacking skills in other craft areas. CMMS allows managers to review this information, what work has been done and by who over a period and assign work appropriately in a variety of craft areas in the future.
4. Not enough maintenance personnel to handle the workload. CMMS can generate reports on labour requirements for each work order totalling the information by craft and week, showing imbalances and requirements for additional personnel.
5. Machines breakdown just before preventative maintenance is due—CMMS can provide reports for each item of equipment, which can help pinpoint

problem parts or requirements to reduce the preventative maintenance interval.

Wireman is of the opinion that if Computer Maintenance Management Systems are to be properly examined it is important to have an understanding of the primary maintenance functions incorporating (Wireman, 1994, pp. 1-61): maintenance inspections and service, equipment installation, maintenance storekeeping, craft administration. He goes on to outline the objectives of CMMS covering: improved maintenance costs, reduced equipment downtime as a result of scheduled preventative maintenance, increased equipment life, ability to store historical records to assist in the planning and budgeting of maintenance, ability to generate maintenance reports.

Most of CMMS systems have four modules or components catering for:
(a) Work order planning and scheduling,
(b) Maintenance stores controls,
(c) Preventative/predictive maintenance,
(d) Maintenance reporting.

X. CMMS Implementation

Wireman discusses implementation of CMMS, by outlining the steps required up to and including implementation. These steps are (Wireman, 1994, pp. 61):
(a) Analysis of existing systems,
(b) Selection of a suitable system,
(c) Implementation.

As part of the analysis process, the first decision for management to make is whether there is a requirement to implement a CMMS or not. To assist this process Wireman puts forward questions, which should be considered by management such as:
(a) Are maintenance costs rising faster than operation costs?
(b) How much more is being spent on maintenance compared to 5 years ago?
(c) Does management know what it costs to maintain each item of equipment?
(d) Do technicians spend most of their time waiting for work?
(e) Are there storage bins full of spares that never seem to be used?
(f) Does equipment seem to breakdown at the worst possible time with out any advance warning?
(g) Does management have access to information required to properly plan for the future?
(h) Is this information in a useable format?

A committee should head the selection process according to Wireman with members from engineering, maintenance, stores, accounting and data processing. The objectives of these committees include:

• Review of present record keeping systems and paper work flow,
• Planning objectives of the system in the areas of: work order processing, maintenance stores, preventative maintenance, cost controls and required reports,
• Identifying the types of computer systems that are needed,
• Identifying the vendor packages that meet the objectives,
• Evaluation of systems and vendors.

XI. CMMS Ca□e Study

The case study was based on a CMMS implementation in a textile manufacturing company in the Egypt. The company had employee numbers of 110 persons at the time of CMMS implementation. There were a total of nine technicians and a maintenance manager making up the maintenance department.

Existing maintenance within the company was a mixture of ‘repair’ type maintenance and planned maintenance across the various departments. There was anecdotal evidence to suggest that maintenance was conducted in the plant across all departments, records of which were not always documented, this being one of the major disadvantages associated with manual systems. Analysis of breakdown and cost was not frequently carried out.

XII. Management organi□ation and level□ of technology

Maintenance policy was documented in the plant as part of the quality management system. The company was ISO9002 certified, and procedures documented in the quality manual addressed to some extent maintenance requirements for the plant. This policy was based on ensuring preventative maintenance was carried out in order to minimise machine break down and maximise product quality. Maintenance management had a vision of existing maintenance policy and were of the opinion that older manual based systems could be greatly improved. This could be achieved by automating non-value added administrative tasks, implementing systems which allowed analysis of maintenance performance and developing procedures and systems which would cater for control of spare parts. There were purchase requisition and approval procedures in place to cater for normal day to day expenditure within the maintenance department. Capital expenditure within the maintenance department was initiated by the maintenance or production manager and approved by the general manager. Larger scale capital expenditure required approval from management within the company group. The maintenance manager who was responsible for planning and scheduling maintenance and supervisory management of personnel headed the maintenance department. Other responsibilities incorporated in this job description included ensuring that there were adequate stocks of spares available for all departments, order initiation and purchasing of spares and liaison with machine manufacturers in relation to installation and commissioning of new machines or fault finding and repair of existing items of equipment. Compounded with this the manager was also involved with management of facilities as part of a recent plant upgrade and extension. All these non-value-added duties were extremely time consuming especially as there were no dedicated software systems on hand to assist in any of these areas.

Levels of technology involved newer machines being computer controlled having reasonable levels of sensor technology built in to assist diagnosis and finding of faults. Technology was very dependent on pneumatic, hydraulic, electrical and mechanical actuator systems with high levels of computer and programmable logic control. Sensing and control were very dependent on analogue and digital electronics. Older machines were predominately mechanically controlled.

XIII. CMMS Implementation Procedure

The first task prior to implementing a suitable CMMS was to establish an implementation team. The members of this team were the general manager, production manager, maintenance manager, the company accountant, an individual from maintenance (craft) and one from production as well as an external facilitator (consultant). The function of this team was to draw up an implementation plan and consequently implement a suitable Computer Maintenance Management System in the company. Crucial to this implementation was a review of existing systems; this was carried out in the form of a detailed audit. This audit evaluated systems practised within the plant and assisted in the decision making process enabling an organised implementation plan to be formulated.

XIV. System Preparation

The next stage of the implementation was to make preparations for the new system. This involved modifying existing practices within the maintenance department. Evaluating Computer Maintenance Management Systems software was an integral function of these preparations as well as purchasing and loading up the most suitable package. Several software packages were evaluated under the following criteria: purchasing functions, equipment record capabilities, inventory functions (spares), labour evaluation, reporting and analysis of maintenance, scheduling of maintenance, security of system, statistical predictive maintenance, tasks, work orders and associated functions, work requests and corresponding capabilities, cost of system (3 users) and add on capabilities. The package, which proved to be most suitable for the application in question was Datastream MP2 developed by Datastream. Included here also was a review of existing data and a total reorganisation of the spare parts stores, changing the stores to a new location and discarding of redundant spares. The initial hardware setup in the plant involved loading the software in a manner where it was networked and available on the maintenance manager’s PC, the production manager’s PC and a third terminal located in the workshop/stores area. It was preferable to have the facility to extend the software license to other terminals throughout the plant if the need arose in the future. The task for physically inputting data into the Datastream CMMS was given to two engineering undergraduates contracted for the summer period under the close supervision of the production manager and the maintenance manager. The implementation team worked in conjunction with in-house maintenance craft technicians to setup the system involving: loading the asset manager, loading the spares manager, loading the work control manager, employee information and codes.

The final stage of the analysis was to test the new systems after a suitable operating duration. Several indicators were chosen for evaluation of performance and efficiency of the new maintenance management system. This evaluation was carried out using information such as spare parts costs and production reports. An investment analysis was carried out along with a bench marking exercise to compare the new systems with those, which are representative globally.

XV. CMMS Implementation Results

Analysis and evaluation of the CMMS implementation was carried out after 7 months of successful operation of the system. The cost of spares reduced while production increased substantially. The payback period was relatively short (6 months) for a project investment of this type. The bench marking exercise carried out at this stage in operation of the system produced metrics which were globally representative for maintenance in the manufacturing sector.

XVI. Concluding Remarks

Many benefits accrued from the CMMS implementation after 7 months in operation such as reduced cost of spares, uptime improvements, and increased equipment availability, reducing lead times,

increased morale, reduction in unscheduled maintenance and streamlining of work orders schedules. Evidence of these benefits was supported by several key performance indicators, which were evaluated.
Sizeable increases in production output can be seen in the seaming department, where production was very dependent on maintenance activity due to the high levels of pneumatic, hydraulic and electrical technologies being utilised here. Increases in the region of 500–640 threads per hour could be seen in the latter half of the year. This was the largest department in the plant with respect to quantity of machines and levels of personnel. Other costs such as labour costs, equipment downtime costs, plant shutdown costs and CMMS implementation costs were also evaluated in the form of a return of investment analysis. This analysis resulted in a 0.46-year payback period which was very favourable for a project implementation of this type. The investment proved to be very successful based on cost estimates and finally a bench marking exercise was carried out to evaluate company progress in relation to international practices. This indicated representative comparison between the company and others globally as can be seen from the different indices calculated.

XVII. Conclusion

To demonstrate that reliability and maintainability are crucial to the survival and competitiveness of an organization, especially with the rapid proliferation of technology. We have focused on organization-wide commitment to maintenance and reliability management. This is necessary to obtain the participation and active support of every member of the organization. Through organization-wide involvement, key problems with maintenance and reliability could be identified. We presented different strategies on how problems affecting the process could be identified. Particularly, we focused on identifying the root causes of the problems using the popular four ms – man, machine, methods and materials. Once these problems are identified, they could be considered for inclusion in designing or re-designing a process. The use of quality function deployment for that purpose is recommended. Finally, the paper outlined the strategic implications of considering an organization-wide approach in dealing with maintainability and reliability issues.

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