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Trends and Perspectives in Industrial Maintenance Management

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Abstract: - *With increased global competition for manufacturing, many companies are seeking ways to gain competitive advantages with respect to cost, service, quality, and on-time deliveries. The role that effective maintenance management plays in contributing to overall organizational productivity has received increased attention. This paper, presents an overview of trends and perspectives in industrial maintenance. The results of benchmarking studies from different company are presented and compared. Implications of the trends and perspectives for the management of maintenance are highlighted. Case studies that examine maintenance methods, knowledge, organization, and information systems in three manufacturing firms are used to motivate the discussion.*

What is maintenance?

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. In this paper, maintenance is interpreted in the context of industrial systems (such as production facilities, buildings, equipment, and so on). The main purpose of this paper is to present the managerial implications of industrial maintenance trends.
World Class Maintenance Management refers to maintenance planning as "the last frontier" for manufacturing facilities. In the move to world-class manufacturing (WCM), many firms are realizing a critical need for effective maintenance of production facilities and systems. With the trend to just-in-time (JIT) production and flexible, agile manufacturing, it is vital that maintenance management becomes integrated with corporate strategy to ensure equipment availability, quality products, on-time deliveries, and competitive pricing. The changing needs of modern manufacturing necessitate a reexamination of the role that improved maintenance management plays in achieving key cost and service advantages and of the contribution that maintenance improvement can make to the "learning organization."

Numerous technological and managerial trends for the past two centuries have changed the requirements and content in maintenance. For example, the development of the automobile led to a worldwide network of distribution systems for spare parts and maintenance services. Similar systems have later been designed for many other industrial products (for example, ship engines, airplanes, and industrial production). The development of air transportation, satellites, telecommunication systems, and so on have led to new standards for design of technological systems and for maintenance requirements based on 100% system functionality. The development in maintenance requirements has been supported by advances in information technology that have given new possibilities for maintenance performance.

Developments in the chemical industry (such as oil refineries, plastic and dyestuff factories, biochemical companies, and pesticide manufacturers) have added some new aspects for maintenance: environmental and labor protection. Technological developments have also

given the maintenance area new tools and methods: nondestructive material tests, automated data collection systems, computer tools, video technologies, and so forth. New trends indicate more application of computer systems for diagnosis and analysis.
In addition to technological changes, several trends in management have changed the view points on maintenance. Managerial attitudes have changed toward maintenance because new management philosophies, such as JIT, have focused on reduced time for delivery or enhanced quality. Trends with job enrichment and automation have led to embedding maintenance information technology in products and production equipment, with corresponding changes in maintenance jobs from mechanical to electronic. Sociological trends, such as lack of capital, fluctuations in currencies, competition, quality, and environmental consciousness, have also affected the need for maintenance.

Case studies of three companies are presented and emphasized on the managerial implication on maintenance.

Benchmarking of Maintenance

It is observed that the importance of maintenance in society, or more specifically in industry, can be described in different ways by using various measures, such as:

1. Accounting of the total maintenance cost.
2. Percentage of maintenance cost to total production cost or capital cost in assets.
3. Total number of personnel working with maintenance-or percentage of maintenance personnel to total number of production personnel.
4. Possible consequences for lack of maintenance: financial, environmental, human, equipment damage, and so on.

Why bench marking?

The aim of the benchmarking study was to establish a trade-by-trade overview of maintenance methods to assist companies in identifying areas for improving maintenance. As such, general maintenance trends may be induced from the report. It must be remembered that many dynamic factors make interpretation of the study's results among countries difficult. Some of these factors are due to varying age and quality of machinery and buildings, interpretation/use of maintenance concepts, varying environmental conditions, differing forms of production operations (number of shifts, production technology, and so on). The benchmarking study was based on an analysis of questionnaire responses from industrial companies of similar type

Approximately 39% of the time spent on maintenance is used for unforeseen repairs, 20% for preventive maintenance, and 37% for planned repairs. Planning and control of preventive maintenance is performed in 45% of the companies. Use of the computer to control spare parts increased from 10% to 50% in recent years, and computer usage to control preventive maintenance increased from 9% to 60%. However, 25% of the companies do not have any inventory control procedures in place for spare parts.

The principal maintenance problems were, schedule conflicts, hiring, breakdowns, training, excessive inventories, lack of management support, and budget control. One of the primary reasons for the failure of maintenance management systems is that frequently the planning and supervising functions are mixed in an organization. Such a situation creates confusion and leads to a reactive rather than proactive approach to maintenance management.

Two major trends in the development of maintenance management research identified by the benchmarking studies may be succinctly stated as:

1. Emerging developments and advances in maintenance technology, information and decision technology, and maintenance methods; and
2. The linking of maintenance to quality improvement strategies and the use of maintenance as a competitive strategy.

The second major trend is typified by the emergence of total productive maintenance (TPM), which is a relatively new approach to the development of maintenance systems.

The concept of TPM

TPM is a lifecycle and employee involvement approach to maintenance management that:

1. Tries to maximize overall equipment effectiveness and overall efficiency.
2. Develops a preventive maintenance program for the lifecycle of the equipment.
3. Uses team-based concepts.
4. Involves operators in maintaining the equipment.
5. Uses motivational management (autonomous small groups) to promote preventive maintenance.

In the TPM framework, the goals are to develop a "maintenance-free" design and to involve the participation of all employees to improve maintenance productivity. A metric, termed the "overall equipment effectiveness (OEE)," is defined as a function of equipment availability, quality rate, and equipment performance efficiency.

If a company has an OEE of 85% or more, then it is considered to be a world-class company. TPM also provides a systematic procedure for linking corporate goals to maintenance goals. This procedure considers external and internal corporate environments, development of a basic maintenance policy, identification of key points for maintenance improvement, and finally the definition of target values for maintenance performance. The TPM metrics offer a starting point for developing quantitative variables for relating maintenance measurement and control to corporate strategy.

TPM focuses on eliminating major "losses" encountered in production activities. These losses are decomposed into major losses obstructing equipment efficiency, manpower (personnel) efficiency, and efficiency of material and energy. Based on their links to achieving corporate goals, targets to eliminate or reduce these losses are developed directly for the maintenance task in a production system. Just as in activity-based costing (ABC), where cost drivers are identified, the objective here is to identify variables that can demonstrate causal relationships these maintenance activities have on production system performance. Each of the major equipment losses are functionally related to availability, performance efficiency, and/or quality rate. Thus, the improvement from a maintenance system can be measured by its impact on the OEE. The concept of total productive maintenance is gaining wider acceptance in industrial firms.

The major challenge of industrial maintenance management research is to develop new models and methods that integrate both major trends.

Trends in Maintenance Knowledge

Maintenance modeling is inherently evolutionary in nature. As equipment complexity increases, and as the need for high equipment availability becomes paramount in today's complex, dynamic systems, there has been a corresponding increase in maintenance modeling sophistication

1. Corrective maintenance

Corrective maintenance involves all unscheduled maintenance actions performed as a result of system/product failure to restore the system to a specified condition.
Corrective maintenance includes failure identification, localization and isolation, disassembly, item removal and replacement or repair in place, reassembly, and checkout and condition verification. Preventive maintenance includes all scheduled maintenance actions performed to retain a system or product in a specified condition. These actions involve periodic inspections, condition monitoring, critical item replacements, and calibration.

2. Predictive maintenance

Predictive maintenance is a relatively new concept in maintenance planning. This category of maintenance occurs in advance of the time a failure would occur if the maintenance were not performed. The time when this maintenance is scheduled is based on data that can be used to predict approximately when failure will occur if certain maintenance is not undertaken. Data such as vibration, temperature, sound, color, and so on have usually been collected off-line and analyzed for trends.

With the emergence and use of programmable logic controllers (PLCs) in production systems, equipment and process parameters can now be continually monitored. With condition-based maintenance, the PLCs are wired directly to an on-line computer to monitor the equipment condition in a real-time mode. Any deviation from the standard normal range of tolerances will cause an alarm (or a repair order) to be automatically generated. Installation costs for such a maintenance system can be high, but equipment service levels can be significantly improved.

3. Intelligent maintenance

Intelligent maintenance, or self-maintenance, involves automatic diagnosis of electronic systems and modular replacement units.14 Sensor data from remote facilities or machines would be provided on a continuous basis to a centralized workstation. From this workstation, the maintenance specialist could receive intelligent support from expert systems and neural networks for decision-making tasks. Commands would then be released to the remote sites to begin a maintenance routine that may involve adjusting alarm parameter values, initiating built-in testing diagnostics, or powering standby or subsystems, for instance. The U.S. Federal Aviation Administration (FAA) is developing the Remote Maintenance Monitoring System (RMMS) that is an example of the future direction in maintenance automation." In some cases, robotics may be used for remote modular replacements.

Maintenance Improvement Connected to Organizational Learning

In the quest toward world-class manufacturing, many industries are appreciating the need for efficient maintenance systems that have been effectively integrated with corporate strategy. New production management techniques, such as JIT and flexible and agile manufacturing, demand quick response times and equipment availability.

As new methods and technologies evolve for maintenance planning, such as expert systems, constraint-based reasoning, belief networks, and artificial neural networks, there is an important need to develop a broader framework to ensure that these methods become integrated into the modus operandi of an organization. Otherwise, there exists the real possibility that the new methods and technologies for maintenance management may become "islands of automation" that will not provide any meaningful feedback to improve organizational performance. New methods for reliability prediction and maintenance diagnoses coupled with the use of maintenance automation technology offer significant promise in helping to meet the global demands of competitive pricing, quality, and on-time deliveries.

Such an approach will prevent the situation where a new maintenance system is developed in isolation and views the system development as an interactive, collaborative process with due regard to the mutual interrelationships to the other three learning perspectives. This integrative approach encourages the development of individual qualifications for maintenance technicians rather than relying extensively on the procedures embedded in a computerized maintenance management system. The approach also places awareness on collective learning processes as implemented by formal organizational structure and management systems for production planning and control and recognizes the role that informal systems play in operationalizing maintenance concepts. Such an understanding is essential for a successful implementation of new maintenance models and methods that are more quantitative and technology-based.

Case Examples of Maintenance Management

Case examples from industry will be used to illustrate different approaches to maintenance management. These descriptions focus on the "as is" condition of maintenance planning within these companies. The five primary maintenance categories of corrective maintenance, preventive maintenance, predictive maintenance, condition-based maintenance, and intelligent or self-maintenance as defined earlier will be used to classify the maintenance management systems. It must be remembered that there will be overlap among the maintenance categories and that the primary purpose of this classification scheme is to illustrate the distinctions among the different types of maintenance.

To enrich the classification of maintenance management systems in a study of three companies, the factors of tasks, people, technology, and structure in examining organizations are considered. They are used to understand the interdependencies of these four elements but will be included in this section to add more dimensions to the maintenance categories. These elements have been renamed as Maintenance Tasks, Structure and Management Systems, Technology, and People.

Company A

This company produces high-end audio and video equipment, such as televisions, loudspeakers, CD players, tape recorders, and integrated music, audio, and video systems. Customers are located in upper social levels in numerous countries throughout the world. The company is divided into eight factories with seven assembly/production sections and one administrative section.

There are a number of identical machines available. The technology in use involves simple assembly tools and fixtures in the audio section and integrated computer-controlled assembly lines in the video section. The philosophy of the production control system is to be able to deliver customer-specified products in a short delivery time, while at the same time to have no inventory of finished goods. Maintenance is divided into mechanical and electrical tasks.

Maintenance is decentralized and informal. However, at the assembly factory, maintenance is somewhat centralized both formally and informally and placed as a sub-function known as a "production service" function. There is some hierarchical internal maintenance where maintenance is divided into a mechanical section and an electrical section.

The assembly factory is characterized by almost all breakdown or corrective maintenance. Preventive maintenance is done to the machine only when it is not in use. Maintenance involves changing worn-out parts and lubrication of moving contact parts.

Possibilities to coordinate spare parts inventory are not used because the inventory control of spare parts is mainly informal. The information system is so poor it only collects time spent on each job. Rarely is the job type and cause of the breakdown recorded. There is informal planning of preventive maintenance; breakdown jobs are carried out at once, if there is a breakdown. The maintenance technology in use varies just as much as the production technology. There is some registration of repair times used at different jobs.

There is no systematic training on how to maintain new systems. The new maintenance staffs are trained by older members, is well skilled in different maintenance jobs, and possesses the good knowledge of existing systems. However, new systems are not properly introduced, which causes problems.

The poor use of information systems results in lack of collection of knowledge. The knowledge from the maintenance staff is not used by other corporate functions. The maintenance work at Company A is still in a development phase. The usage of information systems is still poor. The maintenance staff is generally motivated to be more involved in various tasks and motivated to supply other functions with knowledge. There exists poor coordination between maintenance and production planners/leaders as well with systems development functions.

The management doesn't focus on maintenance.

Company B

Company B is divided into divisions within different product areas. The factory that was studied is connected to the mobile hydraulic division that produces mechanical steering units for heavy machinery. The case only covers a part of the production process and the description below concentrates on this part.

The factory understudy is a sub-supplier to assembly factories within the tractor industry, which requires accurate and on-time JIT delivery according to customer demand given by their assembly plan. The production philosophy is production of buffer stock in the production area with three weeks of throughput time. The production is in large batch and the process flow can nearly be characterized as a production line. After the analyzed area, there is a pull-oriented assembly area with production directly to customer orders. The product program consists of about 39 different product variants based on nearly the same components, with minor differences.

In the analyzed part of the factory there are about 20 major machines, with almost no standby parallel machines. The machines can be characterized as complex CNC machines, transfer lines, and machine centers of which the major parts of the machines were implemented from the beginning of the company. The machines are normally running in three shifts; some machines run in four and five shifts.

Maintenance is organized centrally under the production manager and can be characterized as mechanistic-oriented. The maintenance tasks are divided into operators, setting-up fitters, and maintenance workers. The operators should perform daily cleaning, but this does not work well. The fitters only perform minor maintenance tasks, but there are some problems with qualifications and coordination. Maintenance workers perform the remainder of the jobs.

Both the maintenance tasks and the workers are divided into mechanical and electronics. Approximately 30% of the maintenance tasks are preventive maintenance, the rest corrective maintenance. The maintenance jobs are given a priority depending on the urgency. Each worker is responsible for his or her own machine.

The company has a traditional centralized information system for maintenance. The system is used for managing the stock of spare parts and for planning preventive maintenance. The information system is used to coordinate the stocks of spare parts across the factories in the company. In addition, there are log books placed at each machine, but they are not used regularly.

The maintenance function uses SPC (statistical process control) to measure the machine conditions and the need for preventive maintenance or major overhauls. A central quality functions takes calibrations and minor machine tests (such as oil tests), which are carried out regularly.

There is poor, informal coordination in planning between production and maintenance. There is no performance measures connected to daily maintenance, and the only measurement connected to the machine conditions is SPC measurement.

The management focus on maintenance is based on capacity utilization in the production area.

Company C

Company C manufactures products for the hospital sector, such as protheses and other devices to assist people recovering from operations. The case study focused on the factory that produces parts for the other factories in the company.

The production philosophy in the factory is pull oriented demand from the other factories, with approximately two weeks of buffer stock on most products. There are local stocks of finished goods in each sales company.

The production process consists of few processes and machines. The first part of the production is characterized as a production line with production in large batches. The last part of production involves two minor process centers/machines. Most machines are company-designed and constructed. The production equipment is complex and sensible according to quality, process parameters, and tolerances. Production occurs in three shifts during the first three days in the week. The remaining two days are used for maintenance and other tasks.

The company has a mission to minimize documentation and formal business processes. The production is organized as local production centers. Many support functions are integrated into the production centers. Daily maintenance tasks are assigned to a maintenance operator at each production center. The maintenance function is organized as a staff function to the plant manager. The function has seven employees, of which one to three is working with maintenance. The rest is working with building new machines and construction changes on existing machines. The preventive maintenance jobs use one employee. Each maintenance worker has an assigned machine/production area of responsibility.

An operator at each production center has the responsibility for maintenance and changeover. This operator has technical education and performs minor tasks. The company uses no EDPbased information system for maintenance. Some PC-based programs are used in planning preventive maintenance, but most plans are made manually. The only recording of maintenance is that the preventive maintenance jobs have been completed. Some of the registrations are made in a log book at each machine. Maintenance has first priority, and a new project has second priority. There are no economic valuations of each machine's importance to production.

To ensure an educated maintenance staff, there is an education plan for each maintenance worker. The education is connected to the tasks in the production area where the worker is responsible for maintenance. Maintenance workers cannot operate the different production machines and do not have any knowledge of the production flow.

There is no formal cooperation between maintenance and production planning. There are no measures-only that the preventive maintenance jobs have been completed. One of the reasons is that the maintenance function does not have clear goals related to production. Also there is no follow-up on maintenance costs. Most maintenance costs (salaries) are hidden in the production centers and in new projects.

Management focus is that the maintenance function is a necessity but needs to be minimized and invisible.

General Observations from Case Studies

A number of general observations may be made from analyzing these three case studies of companies. The general observations are summarized below:

An analysis of the case studies suggests that formal systems will deteriorate if not meaningfully reinforced. Maintenance workers must be motivated and top management must see a clear link between maintenance activities and corporate objectives. The case studies reveal that the maintenance sections were not involved in production systems development. This observation is consistent, which showed a general lack of integration between the maintenance and production functions.

The case studies reveal a lack of maintenance resources in the companies. As is frequently the case, the concern for the execution of daily operations diminishes the capability for long-range maintenance planning. Also, the maintenance planning and supervision functions were mixed. Such a situation lead to more supervising than planning. In the companies studied, the motivation of production personnel to perform basic maintenance was weak. A key observation emerging from the case studies is that the knowledge base for maintenance was not systematically organized or structured. This organization of maintenance knowledge is a prerequisite for improving maintenance performance. All the case companies were struggling with the quantification of maintenance metrics.

The case studies illustrate the need to better integrate maintenance planning with the production function and highlight the need for a broader framework for maintenance systems development. Thus it needs to develop maintenance systems that may be used with different organizational structures and may include combinations of centralized and decentralized maintenance activities as well as outsourcing of certain maintenance functions.

The fundamental managerial implications for maintenance from analyzing the case companies may be succinctly stated as follows:

1. A situational approach to maintenance systems development is needed due to varying company dynamics, products, processes, technologies, and market influences. The maintenance function needs to be integrated with production systems development, organizational structures, people, and information technology issues.
2. Current maintenance systems have poor links to corporate strategy, which leads to a deterioration of formal systems due to lack of meaningful reinforcement.
3. The knowledge base in a company for maintenance is typically not well organized, structured, or current.

Conclusion

Despite advances in computer technology and manufacturing techniques, benchmarking studies of actual maintenance performance signal the need for new, improved methods for analyzing and designing maintenance systems that are consistent with novel developments in information technology and management systems. This paper highlighted some of the managerial implications for future maintenance management by examining recent trends in maintenance methods, knowledge, organization, and information systems.