PRIORITIZING CRITICAL BARRIERS OF COMPUTERIZED MAINTENANCE MANAGEMENT SYSTEM (CMMS) BY FUZZY MULTI ATTRIBUTE DECISION MAKING (F-MADM) (USING LFPP)

Ahmad Jafarnejad
Professor of Department of Industrial Management, University of Tehran, Tehran, Iran
Mansour Soufi (Corresponding Author)
Department of Industrial Management, Rasht Branch, Islamic Azad University, Rasht, Iran

Ali Bayati
Ph.D student, Department of Industrial Management, University of Tehran, Tehran, Iran

Abstract
The main aim of this study, are identifying and ranking effective barriers on setup Computerized Maintenance Management System (CMMS) in Shoa-e-Shargh Concrete plant as a case study. Proposed approach is based on Logarithmic fuzzy preference programming method. For rating the factors, with LFPP techniques modeling was performed and with LINGO software weight of each factor was determined. As a result, according to the experts opinion, the critical barriers were rated as F4: Management support > F1: Equipment availability > F3: Maintenance information > F2: Labor productivity > F5: Inventory control > F6: Environment controls.
Keywords: *Computerized Maintenance Management System (CMMS), Logarithmic fuzzy preference programming (LFPP), Fuzzy set, Genetic algorithm*

INTRODUCTION
The word “maintenance” conjures negative connotations in most people’s minds. Frequently, when asked the question “what does the word ‘maintenance’ mean to factories?” people respond with negative examples such as: 1. A machine has broken down; 2.There is some kind of problem with the equipment or the facility; 3.Something needs to be repaired or fixed. These are all negative images, none of which reflect the true meaning of the word ‘maintenance,’ which is defined as ‘*the work of keeping something in proper condition; upkeep*’.” The perception of the word “maintenance” has changed drastically; it has been twisted and pushed into an ugly light. *Ask factories self these questions:* 1.When expenses are cut, what goes first? 2. Typically maintenance resources are cut first because upper management views maintenance as an expense (Mobley RK, 2003). They just look at profit and loss statements and cut expense items to increase profits without realizing the consequences. We have all heard the term downsizing. As an example, if a company decides to downsize its operation by 20 percent, they almost always cut maintenance resources by 20 percent. Maintenance resources are based on company’s assets. When factories downsize, did factories downsize the assets? In other words, did factories get rid of 20 percent of factories production equipment, or 20 percent of factories buildings? No that means maintenance now has to maintain more with less resources. This can have serious impact on a company’s long range survival. 3. How many senior managers come from maintenance? Studies show the

lack of emphasis and importance placed in the maintenance department. 4. How many companies support maintenance R&D? It goes back to the philosophy of how maintenance is viewed. Other departments or areas receive R&D funding as they are viewed as profit contributors. Millions of money is spent on product improvement R&D; sadly, it is forgotten that maintenance is an equal contributor to product quality improvement. Factories can spend millions on product design and quality improvement; but it will not be fruitful if factories do not take care of the production equipment. 5. How many interns are hired for the maintenance department? It would be ideal for a maintenance department to hire some interns to help implement a *computerized maintenance management system* (CMMS) project (Winston, 2003). A CMMS project involves a fair amount of data gathering and data entry. In fact, lack of resources to accomplish this part of the CMMS project is one of the primary reasons for CMMS implementation failures. 6. How many maintenance courses do universities offer? Actually, there are two questions here. How many courses and how many universities? The answer to both is very few. This shows maintenance is not even viewed as a potential career for future graduates (Winston, 2003). Today maintenance is going through major changes. Maintenance concept has undergone several major developments such as the transformation of traditional "fail–and–fix" maintenance practices to "predict–and–prevent" e–maintenance strategies. E–Maintenance provides the opportunity for the 3rd generation maintenance. Personal Digital Assistants (PDA) devices play a key role in bringing Mobile Maintenance Management closer to daily practice on the shop floor. It is now possible to take advantage of radically new technologies (e.g. internet, mobile devices, micro technologies) to re–design maintenance strategies (taking full advantage of existing information structures) to enable cost–effective e–maintenance systems. The networks, integrates and synchronizes the various maintenance and reliability applications to gather and deliver asset information where it is needed. E–Maintenance is a subset of e–Manufacturing and e–Business. Ability to monitor plant floor assets, link the production and maintenance operations systems, collect feedbacks from remote customer sites and integrate it to upper level enterprise applications. A more general definition maintenance management concept where by assets are monitored and managed over the Internet. Internet regarded as a new technology, have led for some companies to replace conventional reactive strategy by proactive vs. aggressive strategies (Lee, 2003). Infrastructure of e- maintenance is a proper establishment of computerized maintenance management system (CMMS) that are the subject of this paper. Maintenance can be defined as the orderly control of activities required to keep a facility in an as-built condition, with the ability to maintain its original productive capacity. Maintenance management simply involves managing the control of maintenance activities. Maintenance is defined by the European Committee for Standardization (EN13306:2001) as 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 (function or a combination of functions of an item which are considered necessary to provide a given service). The same standards defines maintenance management as all the activities of the management that determine the maintenance objectives or priorities, strategies, and responsibilities and implement them by means such as maintenance planning, maintenance control and supervision, and several improving methods including economic aspects in the organization (Laszkiewicz, 2003). A good maintenance management system makes equipment and facilities available. Availability means the production team can demand and receive any item such as light, power, air, gas, heating, cooling, or machine tools when it is needed. If the required equipment or service is down, or if the machine stops short of completing a job, time and money are wasted. A good maintenance management system helps accomplish minimal downtime. Maintenance Management includes corrective, preventive and proactive maintenance, inventory and procurement, work order system, computerized maintenance management systems (CMMS), reliability centered maintenance, total productive maintenance, financial optimization, technical training, and continuous improvement. From an organizational point of view, maintenance management must align actions at three levels of business Activities. Referring to (Marquez, 2007) this means: The Strategic level establishes maintenance priorities in accordance with business priorities. This priorities transformation materialized by a generic maintenance plan will establish critical targets in current operations. In addition, maintenance management at this level is responsible to decide on skills and technologies requirements to improve maintenance effectiveness and efficiency. The tactical level of maintenance management is responsible of the correct assignment of maintenance resources to fulfill the maintenance plan. Hence, detailed maintenance requirements planning and scheduling are established at this level. Tactical maintenance policies are to be improved with experience. The operational level ensures that the maintenance tasks are carried out by skilled technicians, in the time scheduled, following the correct procedures, and using the proper tools. This level of maintenance management is also responsible of data to be recorded for diagnosis and/or prognosis purposes. In this article we will focus on CMMS. Information and Communication Technologies (ICT) is considered as one of the maintenance pillars beside maintenance engineering methods and organizational ones (Marquez and Jatinder, 2006). In fact, CMMS are among the first historical steps of maintenance information systems (Rasovska et al. 2007). A *computerized maintenance management system* (CMMS) is a computer software program designed to assist in the planning, management, and administrative functions required for effective maintenance. These functions include the generating, planning, and reporting of *work orders* (WOs); the development of a traceable history; and the recording of parts transactions (Davis and Mikes, 2003). CMMS is not just a means of controlling maintenance. It is now used as a means to ensure the high quality of both equipment condition and output. CMMS offers core maintenance functionalities. It is not limited to manufacturing; it is applicable to facilities, utilities, fleet, and other types of organizations where equipment/asset is subject to wear, and repairs are done to them. A CMMS usually includes equipment management, *preventive maintenance* (PM), labor tracking, WO, planning, scheduling, inventory control, and purchasing. CMMS usually do not include financial or human resource management (other than basic cost recording and personnel information). Factories can, however, integrate them with financial and human resource applications. *Enterprise asset management* (EAM) evolved from CMMS. With EAM, the CMMS functionality is extended to include financial modules such as accounts payable, advanced cost recording, and advanced human resource management (Dunn, 2007). A basic CMMS includes: 1.Equipment data management, 2.Preventive maintenance, 3. Labor, 4.Work order system, 5.Scheduling/planning, 6.Vendor, 7.Inventory control, 8.Purchasing and 9.Budgeting. These or other modules may work independently or may be integrated (Hemming and Davis, 2003). For example, a CMMS that links the equipment data and WO modules can automatically insert equipment information into a WO as soon as factories enter the equipment ID. The result is a quicker, more accurate WO containing consistent data. The need and use of a CMMS is not specific to any one industry or type of application. Any industry requiring equipment and/or asset maintenance is a potential candidate for using a CMMS. ACMMS is becoming more attractive as more maintenance personnel have become computer literate and price of hardware and software have dropped significantly. Companies are also investing in CMMS as they are designed to support the requirements of ISO 9000, other regulatory agencies, and are a key part of the *total productive maintenance* (TPM) and other modern maintenance philosophies (Cram,1998). This study seeks to identify and rank the major barriers setup CMMS in Iran's industries. It works in two basic steps (Figure 1) using a questionnaire and fuzzy multi-attribute decision making (F-MADM) techniques (using FLPP) are performed.

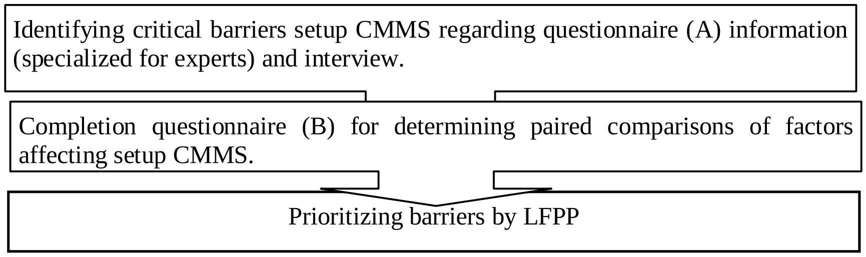

Figure (1): Research design

LITERATURE REVIEW

Maintenance optimization is greatly facilitated when companies adopt a World Class Manufacturing/Maintenance (WCM) philosophy or management strategy in conjunction with CMMS implementation. It was stated that CMMS software was seen first around 1976. Today it is widely used in manufacturing plants all over the world. Wireman (1994) was of the opinion that if CMMS are to be properly examined it is important to have an understanding of the primary maintenance functions incorporating: maintenance inspections and service, device installation, maintenance storekeeping, craft administration. He went on to outline the objectives of CMMS covering: improved maintenance costs, reduced device's downtime as a result of scheduled preventative maintenance, increased device's life, ability to store historical records to assist in the planning and budgeting of maintenance and ability to generate maintenance reports. (Travis *et al.*, 1997) outlined other difficulties associated with modern maintenance management. In their paper the top five problems encountered by maintenance managers were prioritized and suggested that CMMS is the solution to these problems. The problems are outlined as follows:

- Little or no support from management to implement world class maintenance practices, CMMS reports can highlight the levels of downtime and reduce costs.
- 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.

Lamendola (1998) emphasized the need to eliminate non-value added activities especially with respect to documentation of work within maintenance. He stated that "This philosophy has long been the essence of Computerized Maintenance Management Systems." Industries such as oil and gas or nuclear power plants are in need of an efficient CMMS to manage their maintenance activities throughout the plant lifecycle (Supramani, 2005). Ruud (2009) investigated the implementation of CMMS at Sapa Thermal Heat Transfer (Shanghai) on the maintenance department to save on doing unnecessary maintenance and make it easier to order spare part, scheduled maintenance and to see the problems and the solution the problems in the CMMS database. The investigation showed that CMMS contributed to manage the maintenance so much that the machine should have availability above 90 percent. More than 66 articles about CMMS Selection and Implementation listed in www.plant-maintenance.com.

TYPES OF MAINTENANCE

Maintenance can be defined as a set of actions which are carried out to replace, repair and service an identifiable set of manufacturing components, so that the plant continuous to operate at a specified level of availability for a specified time. The main objective of Maintenance is to maximize the availability of machinery and equipment for production. Preserve the values of the plant, machinery or equipment by minimizing wear and deterioration. Accomplish the above goals most economically on a long term basis. By systematic maintenance it is possible to achieve substantial savings in money, material and manpower as every effort is directed towards avoiding catastrophic failures.

Breakdown Maintenance

In this the equipment is attended to only after it breakdown. Despite the numerous disadvantages this type of system may be suitable in certain conditions such as the equipment is noncritical and standbys are available or plant capacity exceeds market demand.

Scheduled Maintenance

Analysis of routine maintenance like cleaning and greasing etc. which will keep the equipment in a good running condition and in a state of operational readiness.

Preventive Maintenance

The objective of preventive maintenance is organizing maintenance before the needs being developed, would minimize the possibility of anticipated breakdowns. It is the cooperative effort directed towards the upkeep and repair of equipment. Effort should be directed to prevent breakdowns or if breakdown occurs, to return the equipment to service in minimum time.

Predictive Maintenance

While the equipment is in actual operating conditions a study of performance of the equipment would reveal whether unexpected deterioration is taking place in it and what be frequencies of scheduled maintenance should be to reduce such deterioration.

Corrective Maintenance

A study of failure of equipment in service may warrant a change in design, material or working conditions of the equipment and corrective steps should be taken thereafter.

Design-Out Maintenance

While designing and developing the equipment objective is set to provide no maintenance or higher maintainability which would reduce the maintenance effort in the life time (Kordic et al., 2006).

COMPUTERIZED MAINTENANCE MANAGEMENT SYSTEM

Most managers find it increasingly difficult to control rising maintenance costs because of inadequate or outdated procedures. One tool that can help is a *computerized maintenance management system* (CMMS). The low cost of PCs and reasonable software cost put them within reach of many small maintenance shops. However, before considering the purchase of such a system, the company has to justify it, which basically means convincing people. How do factories convince different levels of management? First, maintenance managers must determine whether a CMMS is beneficial to their operations. They must ask questions such as: 1.How long can the plant tolerate a production line breakdown due to part unavailability (if maintenance stores are not properly monitored, the company may face more costly breakdowns)? 2. How much more are factories spending on maintenance today than five years ago? 3. Do we have the information we need to plan maintenance operations? 4. Can we get this information when we need it? 5. Is it in usable form? 6. What are the company's plans for operations, for equipment? 7. Will a computer really help? (Wireman, 1994)

The following questions also arise nearly every time maintenance is required on a piece of equipment:

1. Where did we buy that last spare part? 2. How much did we pay? 3. Is this equipment under warranty? 4. Who was the contact person we talked to? 5. What was the phone number? 6. Do we have a blanket purchase order with this vendor? 7. How did we get the last part shipped? 8. What was the delivery time? (Wireman, 2004)

Answers to these questions or inability to answer these will indicate a definite need for a CMMS. CMMS is useful even when the maintenance information system is basically sound but is not easily accessible or more information is needed. Think about factories maintenance system and how it affects other areas of operation such as production, accounting, payroll, and customer service. Could these operations be made more productive by improving the speed and efficiency of a maintenance information system? If the answer is yes, factories could benefit from computerizing factories maintenance system. Another important issue to consider is the amount of information that can leave the company when a key maintenance employee leaves. Years of critical information can be lost the moment the employee walks out the door. Opposing the CMMS acquisition are the internal roadblocks that stand in the way of the system purchase (Ucar and Qiu, 2005). The following list will help factories prepare for common roadblocks associated with acquiring a CMMS:

- *Budget not available now.* This is one of the most common excuses offered by management. It shows lack of acceptance and/or commitment by management.
- *Inadequate project payback or savings.* One must do a thorough job of determining benefits and savings. Factories will find CMMS very easy to justify in most cases.
- *Management information system (MIS) does not give high enough priority.* MIS does not give enough importance to a CMMS project, thus creating a roadblock. If MIS supports the project, its chances of success are increased greatly. CMMS is complicated to many decision makers. Helping MIS understand the importance of CMMS should be a primary goal of every potential user. With MIS on factories side, it is easier to convince others.
- *Failure to reach consensus.* All parties involved disagree on either the need for a CMMS or on the features required in a CMMS.
- *Company too small for a system.* This attitude suggests a basic lack of understanding of the true benefits and functions of a CMMS. It can pay for itself even for very small companies. There are many companies with just one maintenance technician successfully using a CMMS.
- A CMMS will help record and maintain the equipment histories that will be the basis for future repair/replacement decisions. An accurate and complete history can also describe how the job was done the last time, thus saving time associated with job redesign.
- *Prior attempt failed.* Factories should try again.
- *Do not have enough computer capability.* This is a common excuse. Computer hardware and software costs are all part of the justification process. Once the project is justified, purchase of computer hardware is not a problem.
- *Do not believe a CMMS will work in our situation.* As long as equipment requires maintenance, a CMMS will work.
- *Have never considered the benefits.* Factories should consider them now and go through the process of justification (Bagadia, 2006).

IDENTIFYING CRITICAL BARRIERS

Following are procedures that can help factories justify a computerized maintenance program for factories application.

Form a team

The maintenance manager should assign one person (project leader) the responsibility of researching and justifying the CMMS.

Establish a team

The project leader should establish a team to assist him or her in the investigation. The team should consist of the plant engineer, maintenance manager, maintenance employees, and representatives from the data processing, purchasing, and accounting departments. Marketing, sales, and human resources should also be included. Factories should involve everyone who has any impact on this project. At a later date, the coordinator may also need advice from the company's legal department when agreements are needed between the software and hardware vendors (Bagadia, 2006).

Involving factories employees in the automation process enables factories to break down their resistance to computers and build enthusiasm for CMMS as a tool to facilitate their work.

Identify problems with present system

First, determine exactly what problems pertain to the maintenance department. This is crucial to selecting and purchasing the proper CMMS package for company's specific needs. Ultimately, we will determine the optimal system to solve (or minimize) these problems.

For example, two very common problems that exist in companies today are:

- Excessive downtime
- Lack of inventory control

Excessive downtime is a problem that occurs all too often for a variety of reasons. The causes range from lack of *preventive maintenance* (PM) to unavailability of parts when machines are down. The question that should be asked at this point is "can CMMS help with this?" The answer is "Yes." The properly selected CMMS package can help with PM scheduling and better inventory control.

Some problems simply may not be solved with a CMMS, such as employee theft. Discuss and brainstorm with others in the maintenance department and other departments as well. Talk to anyone that factories believe will benefit or be impacted from CMMS. Create a list of factories own with as many descriptive problems as possible within and related to maintenance. Take time to consider the causes, not just the effects. Focus on all factories maintenance problems. Now compare factories list with the following list and check to make sure relevant problems are covered. Feel free to add those to factories list. Reorganize factories list until factories have a final list by categories. Some problems may belong to multiple categories (Table 1).

Table (1): Element and barriers of set up CMMS in industry

Critical Factors	Barriers of implementing CMMS	Source
F1: Equipment availability	1. Spare parts are out of stock 2. Justify upgrading existing equipment 3. Machine no means to monitor and control/too much downtime 4. Planning material is not available when needed to fix a machine problem 5. Crisis management 6. Lack of PM	• Wireman, (1994). • Crespo, (2007).
F2: Labor productivity	7. Shortage of manpower 8. Shortage of crafts to finish job 9. Trouble justifying more manpower 10. Union problems 11. Employee no means to monitor and control 12. Planning material is not available when needed or too much is in stock 13. Planning proper tools are not available or accessible for the job 14. Planning necessary craftspeople are not available to do the job 15. Scheduling problems (manpower, material, equipment, and so forth) 16. Crisis management 17. Rescheduled job priorities 18. Job priorities which to do first? 19. Utilization of manpower resources 20. Looking for supervisor to get the job assignment 21. Visiting job sites to determine what needs to be done 22. Rounding up materials and making multiple trips to the warehouse 23. Looking for tools 24. Waiting for other crafts to finish 25. Waiting for shutdown, clearance, and access to the job site 26. Time wasted due to lack of information or drawings 27. Time wasted due to canceled work orders	• Mobley et al., 2008. • Cohen , 2001. • Cohen et al., 2003. • Barta, 2001. • Wickens, Sallie, Yili.,1998. • Staker, 2003. • Joo, 2009. • Wireman, 2004.

	28. Waiting for special tools or engineering specifications 29. Paperwork wasted time 30. Extended coffee or lunch breaks 31. Late start-up, early wash-up 32. Attitude and motivation 33. Lack of preventive maintenance 34. Paperwork lack of storage space or simply unorganized	
F3: Maintenance information	35. Assets recordkeeping 36. Assets identifying 37. Lack of history records 38. Cost control budgeting/no control over budget	• Long, 2000. • Crespo, (2007).
F4: Management support	39. Management philosophy conflicts 40. Lack of communication with other departments/within the department 41. Lack of support from other departments 42. Lack of management support 43. Lack of long-term planning	• Wireman, 2004.
F5: Inventory control	44. Planning material is not available when needed to fix a machine problem 45. The proper tools are not available or accessible for the job 46. Spare parts are out of stock 47. Too many parts 48. Too many obsolete parts 49. No information available for substitute parts	• Long, 2000. • Joo, 2009. • Crespo, 2006.
F6: Environment controls	50. Government/OSHA regulations 51. Safety procedures and standards	• Kullolli, 2008.

This can provide the following conceptual model (Figure 2).

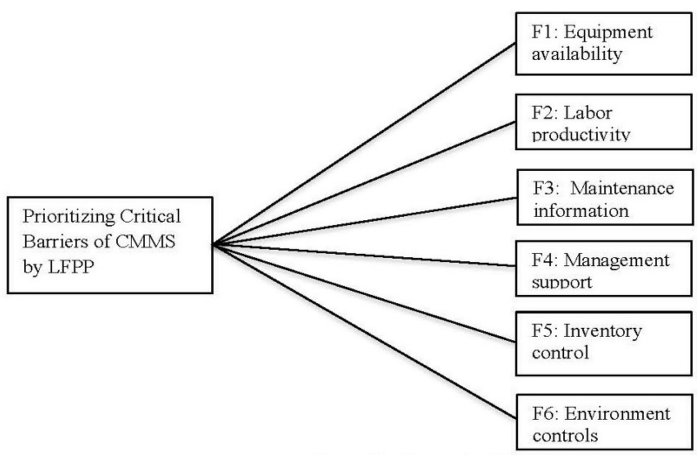

Figure (2): Conceptual Model

SPECIFY, EVALUATE, AND SELECT A CMMS

Once a *computerized maintenance management system* (CMMS) has been justified, the next step is to acquire a CMMS. Where do factories start and how do factories proceed? Factories can either develop the CMMS in-house or purchase ready-made software. Regardless of the option factories choose, it is important to review a number of criteria to make the right selection for factories application. In-house development means software developed in-house by factories own employees or people subcontracted to develop it for factories under factories direction per factories specifications. Ideally, an in-house system offers a great deal of flexibility to a company. It also provides the best link with existing plant information systems because it can be designed to accommodate the needs of other departmental systems. And, the in-house system can be designed to meet the highly specialized needs of a company, while readily adapting to its current maintenance operations. Major advantages of in-house development: 1. It provides the greatest amount of flexibility. 2. It provides the best link with existing information systems. 3. It can meet highly specialized needs. 4. It has potential for optimum training development. 5. It is readily adaptable to current maintenance operations. Major disadvantages of in-house development: 1. High cost; 2. Long development time; 3. Potential for failure to meet expectations: costs, target dates, scope, and system capabilities; 4. High potential for narrow focus in development rather than creative and innovative solutions; 5. Poorly documented in the rush to finish the job (Garcia, 2004). As indicated earlier, the in-house development alternative has a few serious problems. To quickly review, an in-house development could take a long time with a very high cost. With this in mind, it is time to look at purchasing a ready-made software. Research has shown that purchasing software from a CMMS vendor can offer significant benefits to a company, especially in terms of saving time and money (Iung, 2006). The reason for the significant savings in ready-made software is because factories save many of the time consuming factors involved in in-house development. Problems like: 1.Involving extensive programming efforts; 2. Extensive testing and redesign. Because the solutions are developed over a number of years, and designed to meet a variety of needs and specifications, they often prove to have more sophisticated, creative, and innovative approaches to maintenance solutions. These same approaches may never enter into the wildest dreams of an in-house programmer tasked with automating a specific system. Advantages of ready-made software: 1.Relatively low cost. 2. No development time. 3. Shorter implementation time. 4. Provides current state-of-the-art technology. 5. Provides additional features than factories proposed system, thus further improving productivity. 6. Provides the required flexibility to meet factories current and future needs. 7. User groups to help factories get most out of factories software. Disadvantages of ready-made software: 1.It may not link with other existing information systems. 2. It may not meet highly specialized needs (Yoshikawa, 1995). This alternative brings up the questions: “How do I find and select the maintenance software that is best for my application?” If a proper logical selection method is not followed, it may result in the acquisition of software that will not satisfy the company’s needs, and involve delayed implementation, canceled projects, returned software, and frustration. There are a number of ways to select software. Factories can rely solely on those programs that factories see advertised in popular trade journals. Factories can call a competitor and ask him about the system he or she bought. Factories can hire a consultant to figure out what factories would need, based on factories requirements. In an effort to achieve maximum results and return on factories investment, factories, the client, should manage the evaluation, acquisition and implementation process—from start to finish. This way, not only can factories realize the potential benefit and drawbacks of a proposed system, but also factories will be able to select the best package to suit factories current and future needs.

OPTIMIZE CMMS

Maintenance departments in school districts, universities, hospitals, government buildings, and commercial office buildings nationwide increasingly rely on a *computerized maintenance management system* (CMMS) to gather, sort, analyze, and report on essential information related to equipment and facilities performance. Managers use this information, among other things, to set department priorities and cost-justify equipment purchases. In many cases the CMMS is not producing the desired results. The question is, when is the time to upgrade factories CMMS? *Optimization* means determining existing useful features in factories

CMMS currently not being used and start utilizing them to improve productivity. *Upgrading* means determining lack of useful features in factories CMMS and then obtaining them either by upgrading factories current CMMS or by acquiring a new CMMS package. The most important step in the upgrade/optimize process is an audit of factories CMMS. Observations based on audits reveal how audits can form the basis of a CMMS upgrade. The dynamic nature of business operations and the continuous challenge to keep costs down makes periodic audits a necessity if the businesses are to succeed. Two major steps comprise the audit procedure. The first step is establishing a baseline, and the second is comparing subsequent audits to the baseline to measure improvements. Essentially the audit shows strengths and weaknesses. The strengths are continued and the weaknesses are analyzed to establish actions for improvement. For long-range improvements the audits are required at least once a year to continue the improvements (Bagadia, 2006).

TOTAL PRODUCTIVE MAINTENANCE

Total productive maintenance (TPM) is defined as a strategy that introduces elements of a good maintenance program to increase overall equipment effectiveness and improve manufacturing processes. The five key elements or "pillars" of TPM are:

1. Improving *overall equipment effectiveness* (OEE) by targeting the major causes of poor performance. Causes of poor performance include the equipment, parts, supplier, and individual performance. 2. Involving operators in the routine maintenance of their equipment. 3. Improving maintenance efficiency and effectiveness. 4. Improving skills and knowledge training. 5. Designing for operability and maintainability (Tawarah, 2009). It is important to realize how *computerized maintenance management system (*CMMS) supports the key elements of TPM.

1. *CMMS has information that will calculate the OEE in order to determine improvement needs.* The OEE formula accounts for availability, performance, and quality.

$$OEE = availability \times performance \times quality$$

Equipment/asset downtime is monitored in many different ways. Manually via PDA or by machine via monitoring devices. This information, similarly, equipment performance and quality rate of each equipment is fed into CMMS.

2. *Involving operators in the routine maintenance of their equipment.* Whether machine operators do the routine maintenance or maintenance technicians do it, factories still need to track who did the work, when, and material. CMMS will keep track of this maintenance history, and accordingly, generate the necessary work orders with all details of procedure, parts needed, and the like.

3. *Improving maintenance efficiency and effectiveness.* This can be done by proper preventive and predictive maintenance, equipment documentation (safety, schematic diagrams, and so on), repair and maintenance history, spare parts control, and so forth. All this is stored and tracked by CMMS.

4. *Improving skills and knowledge.* CMMS improves skills and knowledge with documentation of all procedures, trouble-shooting history, and equipment history (such as failure codes and corrective action).

5. *Designing for operability and maintainability.* CMMS enables modifications that extend part life, easier maintenance and inspection, improved performance, and extended equipment life while reducing costs. It is evident that a tool such as CMMS is needed to support TPM philosophy (see Fig. 3). Author has shown this in relations to TPM (Bagadia, 2006). Similar analysis can be performed for other philosophies such as reliability centered maintenance (RCM).

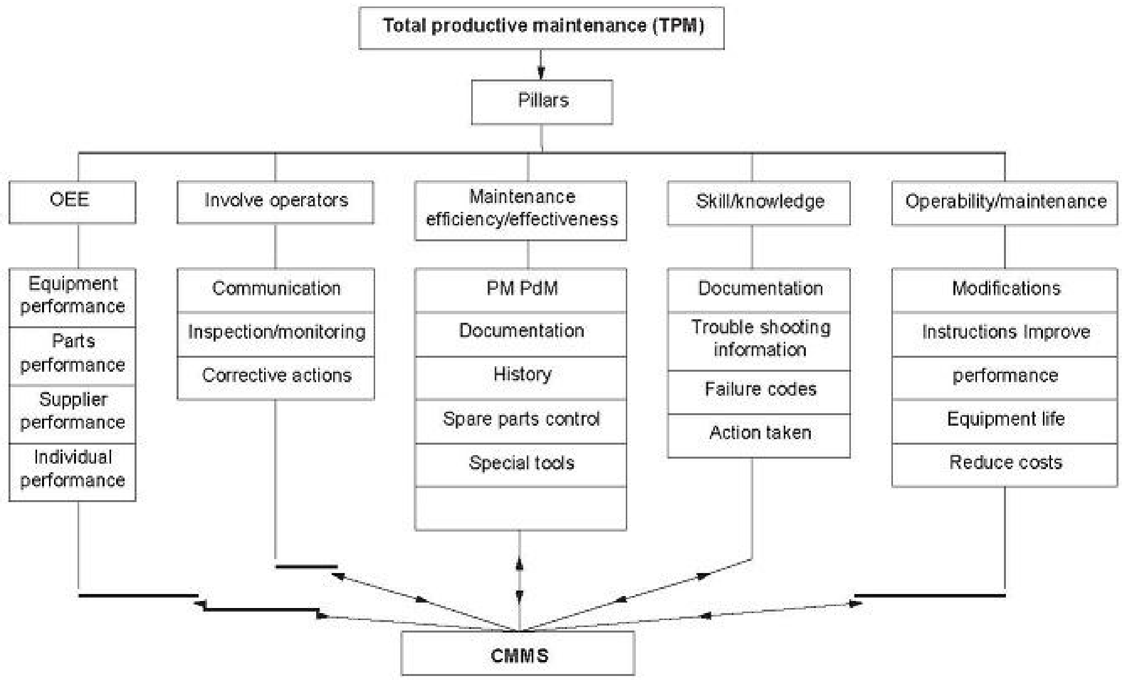

Figure (3): CMMS and TPM (Bagadia, 2006)

FUZZY SETS

Zade (1965) as cited in Dehkordi (2012) introduced fuzzy sets to deal with problem which has a source of vagueness that has been utilized for incorporating imprecise data into decision framework. A fuzzy set $\tilde{A}$ can be defined mathematically by a membership function$\mu_{\tilde{A}}$, which assigns each element x in the universe of discourse X a real number in the interval [0, 1]. A triangula[illegible]mber $\tilde{A}$ can be defined by a triplet (a, b, c) as illustrated in Fig 3.

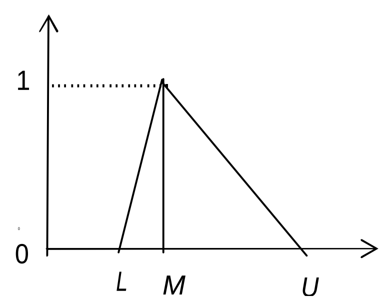

Fig (4): Triangular Fuzzy number $\tilde{A}$

The membership function $\mu_{\tilde{A}}(x)$ is defined as

$$\mu_{\tilde{A}} \begin{cases} \frac{x-a}{b-a} & a \le x \le b \\ \frac{x-c}{b-c} & b \le x \le c \\ 0 & otherwise \end{cases} \tag{1}$$

Basic arithmetic operations on triangular fuzzy numbers,$A_1 = a_1, b_1, c_1$, where $a_1 \le b_1 \le c_1$, and $A_2 = a_2, b_2, c_2$ where $a_2 \le b_2 \le c_2$,can be shown as follows:

Addition: $A1 \oplus A2 = (a_1 + a_2, b_1 + b_2, c_1 + c_2)$ (2)

(3)

Subtraction: $A1 \ominus A2 = (a_1 - c_2, b_1 - b_2, c_1 - a_2)$

Multiplication: if k is a scalar

$$k \otimes A_1 = \begin{cases} (ka_1, kb_1, kc_1), k > 0 \\ (kc_1, kb_1, ka_1), k < 0 \end{cases} \quad (4)$$

$$A_1 \otimes A_2 \approx (a_1a_2, b_1b_2, c_1c_2), \quad if\ a_1 \geq 0, a_2 \geq 0$$

Division: $A_1 \oslash A_2 \approx (\frac{a_1}{c_2}, \frac{b_1}{b_2}, \frac{c_1}{a_2})$, if $a_1 \geq 0, a_2 \geq 0$ (5)

Although multiplication and division operations on triangular fuzzy numbers do not necessarily yield a triangular fuzzy number, triangular fuzzy number approximations can be used for many practical applications. Triangular fuzzy numbers are appropriate for quantifying the vague information about most decision. The primary reason for using triangular fuzzy numbers can be stated as their intuitive and computational-efficient representation. A linguistic variable is defined as a variable whose values are not numbers, but words or sentences in natural or artificial language. The concept of a linguistic variable appears as a useful means for providing approximate characterization of phenomena that are too complex or ill-defined to be described in conventional quantitative terms (Dehkordi, 2012).

LOGARITHMIC FUZZY PREFERENCE PROGRAMMING (LFPP)

In this paper specifically will be used LFPP method to analyze the data and obtain the weight values. It is also used LINGO software for solving LFPP problems for it will be error-free and accurate answers. LFPP method described here in brief. In recent years, Fuzzy Analytic Hierarchy Process (FAHP) as a practical method for solving multi-criteria decision making (MCDM) has found many fans. Weights derived from the matrix of paired comparisons using the AHP method, requires a scientific approach. Method is determined by weight, divided into two categories:

(1) Extraction of a fuzzy number as the weight from the fuzzy paired comparisons matrix.
(2) Extracting a crisp number as the weight from the fuzzy paired comparisons matrix.

The first method would be using the geometric mean, Fuzzy logarithmic least squares method (FLLSM), the maximum Supplier and The objective linear programming (LGP). The second type of methods can be Extent Analysis and fuzzy preference programming (FPP) noted. Because much easier to calculate a crisp number as weight, most people go first followed by the second method.

The first approach of this kind is Extent Analysis was proposed by Chang proposed. Wang soon showed that the weights obtained by this method is not valid and can't show importance of communication and decision alternatives or substitutes to properly. In fact, this method shouldn't be used to derive the weights. The fuzzy preference programming method was proposed by Mikhailovich was also a significant disadvantage. For example, we may use this method to set priorities and conflicting vectors or vectors which are multiples of reach. This non-uniqueness of the solution which makes use of this method is not valid. With an equivalent, LFPP method based on the logarithmic nonlinear programming obtained and proved that it has no objections to previous methods. The objective function and constraints FPP method was as follows:

$$\text{Maximize} \quad \lambda$$
$$\text{Subject to} \begin{cases} -w_i + l_{ij}w_j + \lambda(m_{ij} - l_{ij})w_j \leqslant 0, \; i = 1,\dots,n-1; \; j = i+1,\dots,n, \\ w_i - u_{ij}w_j + \lambda(u_{ij} - m_{ij})w_j \leqslant 0, \; i = 1,\dots,n-1; \; j = i+1,\dots,n, \\ \sum_{i=1}^{n} w_i = 1, \\ w_i \geqslant 0, \; i = 1,\dots,n. \end{cases}$$

(6)

With two follow equivalent, FPP is converted to LFPP. In fact nonlinear equations converted to logarithmic nonlinear equations.

$$\ln \tilde{a}_{ij} \approx (\ln l_{ij}, \ln m_{ij}, \ln u_{ij}), \quad i,j = 1,\dots,n.$$

(7)

$$\mu_{ij}\left(\ln\left(\frac{w_i}{w_j}\right)\right) = \begin{cases} \frac{\ln(w_i/w_j) - \ln l_{ij}}{\ln m_{ij} - \ln l_{ij}}, & \ln\left(\frac{w_i}{w_j}\right) \leqslant \ln m_{ij}, \\ \frac{\ln u_{ij} - \ln(w_i/w_j)}{\ln u_{ij} - \ln m_{ij}}, & \ln\left(\frac{w_i}{w_j}\right) \geqslant \ln m_{ij}, \end{cases}$$

(8)

Finally, a new objective function and constraints are obtained as follows:

$$\text{Maximize} \quad 1 - \lambda$$
$$\text{Subject to} \begin{cases} \ln w_i - \ln w_j - \lambda \ln(m_{ij}/l_{ij}) \geqslant \ln l_{ij}, i = 1,\dots,n-1; j = i+1,\dots,n, \\ -\ln w_i + \ln w_j - \lambda \ln(u_{ij}/m_{ij}) \geqslant -\ln u_{ij}, i = 1,\dots,n-1; j = i+1,\dots,n, \\ w_i \geqslant 0, i = 1,\dots,n. \end{cases}$$

(9)

But in the above calculations, there is still the possibility that λ can be negative. Thus, two non-negative variables η and δ for i and j from 1 to n equations come and the objective function and constraints LFPP, are obtained as follows:

$$\text{Minimize} \quad J = (1-\lambda)^2 + M \cdot \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} (\delta_{ij}^2 + \eta_{ij}^2)$$
$$\text{Subject to} \begin{cases} x_i - x_j - \lambda \ln(m_{ij}/l_{ij}) + \delta_{ij} \geqslant \ln l_{ij}, \; i = 1,\dots,n-1; \; j = i+1,\dots,n, \\ -x_i + x_j - \lambda \ln(u_{ij}/m_{ij}) + \eta_{ij} \geqslant -\ln u_{ij}, \; i = 1,\dots,n-1; \; j = i+1,\dots,n, \\ \lambda, x_i \geqslant 0, \; i = 1,\dots,n, \\ \delta_{ij}, \eta_{ij} \geqslant 0, \; i = 1,\dots,n-1; \; j = i+1,\dots,n, \end{cases}$$

(10)

To solve this problem, a crisp weight requirements phase obtained by paired comparisons. For forming fuzzy matrix used fuzzy linguistic variables as shown in Table (2).

Table (2): The fuzzy linguistic scale

Scale of fuzzy number	Linguistic scales	The linguistic scale and underlying TFN Fuzzy number
(1, 1, 1)	Equally important	$\tilde{1}$
(2, 3, 4)	Weakly important	$\tilde{3}$
(4, 5, 6)	Essentially important	$\tilde{5}$
(6, 7, 8)	Very strongly important	$\tilde{7}$

(7, 8, 9)	Absolutely important	$\tilde{9}$
(x- 1, x, x+1)	Intermediate values ($\tilde{x}$)	$\tilde{2},\tilde{4},\tilde{6},\tilde{8}$
(1/(x+ 1), 1/x, 1/ (x- 1))	Between two adjacent judgments	1/ $\tilde{x}$

CASE STUDY

The study has been conducted in Shoa e Shargh concrete company to present a wide variety of high quality building components such as: Joist, Concrete Block, Clinker Block, Foam Block, Ready Concrete Wall and Fence, Preshrunk Concrete, Mosaic, Terrazzo, Floor Finish, Badbor Tile, Septic Tank, Barbed Wire Column, Column Head , Ready Concrete Chair and Table and etc. Their goal is improving the quality of their productions and reaching high standards by following advanced technology. The company has 77 machines including scale, Lift truck, mixer truck, crane, truck, dumper, concrete breakers like these. The company wants to computerize its maintenance management system for monitoring and control of machines and reduce the cost of emergency repairs. The reason for its favorable CMMS detection, first want to know the barriers of computerization to prioritize them according to experts, take appropriate steps to build infrastructure. In this case, we want to prioritizing critical barriers of CMMS by LFPP. These factors are including: F1: Equipment availability, F2: Labor productivity, F3: Maintenance information, F4: Management support, F5: Inventory control and F6: Environment controls. In LFPP method, we determine the weights of each factor by utilizing pair-wise comparison matrixes. We compare each factor with respect to other factors. See the pair-wise comparison matrix for ranking of these factors in Table (3).

Table (3): Comparison matrix

	F1	F2	F3	F4	F5	F6
F1	(1,1,1)	(6,7,8)	(3,4,5)	(.20,.25,.33)	(6,7,8)	(.50,1.5,2.5)
F2	(.13,.14,.17)	(1,1,1)	(1,2,3)	(4,5,6)	(.17,.20,.25)	(1,2,3)
F3	(.20,25,.33)	(.33,.5,1)	(1,1,1)	(5,6,7)	(4,5,6)	(.11,.13,.14)
F4	(3,4,5)	(.17,.20,.25)	(.14,.17,.20)	(1,1,1)	(4,5,6)	(6,7,8)
F5	(.13,.14,.17)	(4,5,6)	(.17,.20,.25)	(.17,.20,.25)	(1,1,1)	(3,4,5)
F6	(.4,.67,2)	(.33,.5,1)	(7,8,9)	(.13,.14,.17)	(.20,.25,.33)	(1,1,1)

According to Table (3), we formulate the model (10) for the comparison matrix and we solve this problem using of LFPP. In order to employ LFPP, we use the LINGO toolbox. The results obtained from solving non liner-programming using of LFPP algorithm are presented in Table (4).

Table (4): The weight of factor

Factor	F1	F2	F3	F4	F5	F6
Weight	0.207055	0.179459	0.201009	0.219562	0.098242	0.094673

According to Table (4), leadership style (F4) is the most important factor that effect on creativity. Other factors ranked as follow: F4: Management support > F1: Equipment availability > F3: Maintenance information > F2: Labor productivity > F5: Inventory control > F6: Environment controls.

CONCLUTION

In this study, we identified the critical factors affecting the setup of CMMS. This is done using a questionnaire designed by the researcher to collect the opinions of experts about barriers CMMS was launched. Another questionnaire, the relationship between the identified factors was compared in pair. For rating the factors with LFPP techniques, modeling was performed and with Lingo software weight of each factor was determined to be ranked accordingly. As a result, according to the experts, the critical barriers were rated as F4: Management support > F1: Equipment availability > F3: Maintenance information > F2: Labor productivity > F5: Inventory control > F6: Environment controls. During the current study, it was determined that a well-planned and executed *computerized maintenance management system* (CMMS) project can yield a maximum *return on investment* (ROI) realized through increased efficiency, productivity, and profits. However, a poorly planned and executed CMMS project can result in a loss of revenues. These losses can be measured in terms of the overall investment in the project, as well as from wasted time, and lost projected revenue forecast upon the successful installation and implementation of a CMMS. Many CMMS projects fail to reach their full potential and many just plain fail. Here are some of the factors:

- *Not having management support for the CMMS*. The major element necessary to the success of any large undertaking is commitment to the project and support by upper-level management. Lack of interest on the part of upper-level management will diminish the chances of success. If upper-level management approaches it from a rational, reasonable perspective, and provides necessary resources, success is almost assured.
- *Not having adequate supplier support for the CMMS*. This goes back to wrong selection. The best of CMMS will not work well if factories do not get vendor support. That is one of the selection criteria. It is interesting to review aspects that lead to successful implementations of a CMMS.
- *Wrong selection of the CMMS*. This is one of the top reasons of failures. Lot of organizations ended up with the wrong package for their application. Do not feel bad, as there is always a bright side to everything. In the process, organizations have become more educated regarding CMMS and now they know exactly what they want or what they do not want. So, when they are ready for an upgrade to CMMS, hopefully, they will make a right selection.
- *Employee resistance*. Often, employee resistance to computers is not considered when management decides to acquire a CMMS. This problem can be more devastating than losing key members of the project team.
- *Justifying based on advanced functionalities*. Implementation typically has two phases of progression primary and advanced functionalities. Most companies achieve the primary functionalities phase and very few reach the advanced phase. Unfortunately, most organizations justify their CMMS solution based on the advanced phase. Factories should try to justify factories CMMS based on achieving primary functionalities. Further achievements are a bonus that will make the overall implementation of factories CMMS a great success.
- *Being locked into restrictive hardware/software*. Sometimes corporate policies dictate hardware as well software requirements. The best CMMS factories find may not work on company required hardware, or a particular CMMS is required to be used by all

their facilities. Some of these policies make sense but sometimes do not work well as needs of each facility might be different, requiring different solutions.

- *Lack of adequate training during implementation*. If users do not know how to use the software effectively, factories will not have a successful implementation. Training of users is very important.
- *Lack or absence of follow up and monitoring*. This goes back to lack of upper management commitment. Proper follow-up of the project to ensure the continuity is important.

REFRENCES

1. Badia, F.G. and M.D. Berrade, (2006), Optimum maintenance of a system under two types of failures. Int. J. Mater. Struct. Reliab, 4:27–37.
2. Bagadia Kishan.(2006). Computerised Maintenance Management Systems Made Easy, McGraw-Hill.
3. Barta RA., (2001). A computerized maintenance management system's requirements for standard operating procedures. *Biomedical Instrumentation and Technology,* 35(1):57-60.
4. Chang, B. et al., (2011). Fuzzy DEMATEL method for developing supplier selection criteria. Expert Systems with Applications. 38, 1850–1858.
5. Cohen T. (2001). Computerized maintenance management system. *Journal of Clinical Engineering*, 26:200–211.
6. Cohen T et al., (2003). *Computerized maintenance management systems for clinical engineering.* Arlington, Association for the Advancement of Medical Instrumentation.
7. Cram, N., (1998). Computerized maintenance management systems: A review of available products. J. Clin. Eng. 23(3):169–179.
8. Crespo Marquez A, Gupta JND (2006) Contemporary maintenance management: process, framework and supporting pillars. Omega, 34(3): 313-326.
9. Crespo Marquez A, (2007). On the Definition of Maintenance Management. In The Maintenance Management Framework, 3–10. Springer Series in Reliability Engineering. Springer London.
10. Davis, D., and J. Mikes, (2003), "Reaping the Benefits of CMMS," *Maintenance World.*
11. Dehkordi, A. et al., (2012). Investigating the Effect of Emotional Intelligence and Personality Traits on Entrepreneurial Intention Using the Fuzzy DEMATEL Method. International Journal of Business and Social Science. 3 (13).
12. Dunn, S. (2007), "Implementing a Computerized Maintenance Management System," at www.plant-maintenance.com.
13. EN 13306:2001, (2001). Maintenance Terminology. European Standard. CEN (European Committee for Standardization).
14. Fontela, E. and Gabus, A. (1976). The DEMATEL observe, Battelle Institute, Geneva Research Center.
15. Garcia E, Guyennet H, Lapayre JC, Zerhouni N, (2004) A new industrial cooperative tele-maintenance platform. Computers and Industrial Engineering, 46(4): 851-864.
16. Hemming, R.J. and D. L. Davis, (2003), "Eat an Elephant-Implement a CMMS," *Maintenance World.*
17. *IEEE Standard Glossary of Software Engineering Terminology*, IEEE-STD-610.12- 1990, Institute of Electrical and Electronic Engineers, New York, 1991.
18. Iung B, (2006) Research and development on E-maintenance: Survey of some recent advantages and directions. In: Proceedings of the 2nd international conference on Maintenance and Facility Management, Sorrento, Italy.
19. Jassbi, J. et al., (2011). A Fuzzy DEMATEL framework for modeling cause and effect relationships of strategy map. Expert Systems with Applications. 38. 5967–5973
20. Joo, S., 2009. Scheduling preventive maintenance for modular designed components: A dynamic approach. Eur. J. Oper. Res. 192:512–520.
21. Kordic Vedran, Lazinica Aleksandar and Merdan Munir. (2006). Manufacturing the Future: Concepts, Technologies & Visions, publication@ars-journal.com.

22. Kullolli I. (2008). Selecting a computerized maintenance management system. *Biomedical Instrumentation & Technology*, 42:276–278.
23. Lamendola, M., 1998. Repaire more, repaire less: where to focus, EC & M Electrical Construction of Maintenance. 98:56.
24. Laszkiewicz M, (2003) Collaborative maintenance: A strategy to help manufacturers become lean, mean, and agile. Plant Engineering, 57(9): 30-36.
25. Lee J, (2003) E-manufacturing: Fundamental, tools, and transformation. Robotics and Computer-Integrated Manufacturing, 19(6): 501-507.
26. Long, B., 2000. Why CMMS implementations fail. Plant Engineering. 54:30.
27. Mobley RK, (2003) An introduction to predictive maintenance (2nd ed.). Boston: Butterworth-Heinemann.
28. Mobley R. Keith, Higgins Lindley R., Wikoff Darrin J. (2008). Maintenance Engineering Handbook, 7end, McGraw-Hill.
29. Ruud N, (2009), Databaserat hjälpsystem för kontrollerat underhåll computerized maintenance management system, M.Sc, Thesis, Linköpings University, Sweden.
30. Rasovska, Ivana, Brigitte Chebel-Morello, and Noureddine Zerhouni. (2007). Classification Des Différentes Architectures En Maintenance.In proc. 7e Congres international de genie industriel Trois-Rivieres, Quebec (CANADA).
31. Staker T. A (2003). paperless computerized management information system for clinical engineering. In: Cohen T et al, eds. *Computerized maintenance management systems for clinical engineering.* Arlington, VA, Association for the Advancement of Medical Instrumentation.
32. Supramani T, (2005), Development of computerized maintenance management system (CMMS) for ready mix concrete plant production Facilities, Thesis, Universiti Teknologi Malaysia.Malaysia, Malaysia.
33. Tawarah A.M. (2009). Implementation of six sigma on corrective maintenance at the directorate of biomedical engineering in the jordanian ministry of health, Msc 2009, Thesis, Hashemite University, Zarqa, Jordan.
34. Travis, D.E. and L. Casinger, (1997). Five causes of and remedies for maintenance manager headaches. Plant Engineering, 51: 144.
35. Ucar M, Qiu RG, (2005) E-maintenance in support of e-automated manufacturing systems. Journal of the Chinese Institute of Industrial Engineers, 22(1): 1-10.
36. Wang, B., Furst, E., Cohen, T., Keil, O. R., Ridgway, M., and R. Stiefel, (2006). Medical equipment management strategies. Biomed. Instrum. Technol. 40:233–237.
37. Wang J, Tse P, He LS, Yeung R, (2004) Remote sensing, diagnosis and collaborative maintenance with Web-enabled virtual instruments and mini-servers. International Journal of Advanced Manufacturing Technology, 24(9-10): 764 – 772.
38. Wang, H., 2002. A survey of maintenance policies of deteriorating systems. Eur. J. Oper. Res. 139:469–489.
39. Wickens CD, Sallie EG, Yili L. (1998). *An introduction to human factors engineering*. New York, Addison-Wesley Educational Publishers.
40. Winston, C. (2003), "Critical component of the CMMS: the repair work order", available at: www.
41. mt-online.com/current/0103_cmms_repairorder.html (accessed, 21 February 2003).
42. Wireman, T, (1994). Computerised Maintenance Management Systems, 2 end., Industrial Press.
43. Wireman, T, (2004). Benchmarking Best Practices in Maintenance Management, Industrial Press.
44. Yoshikawa H, (1995) Manufacturing and the 21th Century. Intelligent manufacturing systems and the renaissance of the manufacturing industry. Technological Forecasting and Social Change, 49(2): 165-213.