JJMIE

Volume 5, Number 3, June 2011
ISSN 1995-6665
Pages 227 - 234

Jordan Journal of Mechanical and Industrial Engineering

Computer–Aided Maintenance Planning System for Industrial Companies

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Abstract

Significant advances in computer hardware and software development have affected most areas of business and industry, and the area of maintenance planning and management is no exception. The use of computerized maintenance management systems, which are commonly referred to as CMMS, is no longer a luxury or frivolous business overhead; in many cases, it is requirement. Enterprises that want to attain ISO, QS certification will discover that application of CMMS is a fundamental requirement to successfully obtain and maintain such certifications.
A variety of software packages are available, and many have been around for a number of years. Today, CMMS are used for all aspects of maintenance planning, management and control. CMMS must be flexible and adaptable, because every firm is considered unique. A general guide has been developed, which can easily be applied to specific situations to assist in justifying the computer for Maintenance System Evaluation (MSE). MSE has always required the manipulation of large amounts of data and development of more cost-effective processing storage and database systems has brought the use of computers to the fore in this area. Since, the relationships are complex between factors affecting maintenance activities and their interactions; a computer-aided model is developed with main purpose of determining the evaluation factors and their pointers. This model will approximate the complex relations for practical purposes. A model with eight various factors and there pointers for MSE were proposed in this paper. The MSE approach uses the input data as well as the factors that reflect unique operating conditions and specific objectives of the firm. The model would help in measuring the effectiveness of maintenance activities in order to determine the deviations from the planned work. It will also perform instant corrective actions required according to the degree of deviation and its effect on the production continuation and with the minimum shutdowns possible.

Keywords: Computerized Maintenance Management Systems (CMMS); Computer- Aided Maintenance; Maintenance System Evaluation (MSE); Maintenance Activity Factors; Effectiveness of Maintenance Activities; and Maintenance Planning

1. Introduction

In today's global economy with fierce competition to attain and maintain the competitive edge in productivity and quality, a key factor often is neglected. The planning and management of productive maintenance activities in industrial manufacturing organizations rarely are given the attention they deserve Stephens [22]. Many solutions are being exposed, such as future automated factory, zero inventories and integrated manufacturing system. These solutions cannot be successful without highly reliable machines and equipments.

Two issues regarding computer-aided maintenance are addressed: The first is fundamental knowledge, including both theories and methodologies required for practitioners to perform maintenance activities effectively. The revolutionary advances in information telecommunication, and computing technologies at modern factories forced the need for new approaches in process design, materials management, technologies, and human resources. The second and equally pressing issue is to understand how to implement the right maintenance tools and techniques, based on the introduced theories and methodologies, to solve problems in a very short time in order to guarantee success Lee and Wang, [13]. Today, leading firms understand the necessity of linking production planning with resource supply using dependent demand techniques like Enterprise Resource Planning (ERP) in order to provide the increasing business needs in more effective and efficient ways Spathis and Constantinides [21].

The knowledge that has been gained in linking production with maintenance planning is essential to compressing the computer- aided evaluating system for maintenance activities. Applying this knowledge will help reduce waste and greater productivity. It became apparent that maintenance was not just about keeping machinery in a good working order but it involved learning by sharing communal experiences, and feeding the result back into design, operation and maintenance itself [4].Maintenance has always been in the business of dealing with large amounts of data. The advent of the microcomputer in the late 1970s began a revolution in maintenance systems.

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  - Volume 5, Number 3 (ISSN 1995-6665)

Only now, in the mid-1980s, are we beginning to saw a mature system which addresses the following maintenance tasks Carter [4] and Retterer and Kowallski [19]. System Fault Reporting / Repair Control, Labor Control and Reporting, Equipment / Spare Parts Inventory Control, Maintenance Data Recording Analysis.

This research aims in developing a computerized program for evaluating maintenance system's activities so that the maintenance performance level can be evaluated as well. In the age of minimal inventories and highly automated complex machinery, automated maintenance systems are required to truly accomplish the goals of a Computer-Aided Manufacturing (CAM) and Computer-Integrated Manufacturing an automated and maintenance planning and diagnostics system can provide a rapid planning and scheduling response to changing system conditions (CIM) Lin and Chen [14].

Lee and Wang [13] and Candy [3] both suggested that the overall goal of the maintenance function is to make capacity available to production in a reliable and stable manner. This should enable organizational objectives such as the following to be met; 1) Responsive customer service, 2) Consistent product quality, 3) Reliable product output, 4) Cost efficient operations, maintenance and supported departments, and 5) High utilization of equipment and other resources.

In the past two decades, changes in the production environment have made the task of making decisions about allocating maintenance resources and scheduling maintenance work more difficult. An information-processing model is applied by Laura Swanson [11] to study how the maintenance function applies different strategies to cope with the environmental complexity. Computer-Aided Reliability-Centered Maintenance (RCM) a based plant maintenance management system has been studied and investigated by Hossam A. et. al. [8], and Jesu´s Carreteroa et.al.[10]. A survey of models and algorithms for winter road maintenance system design for snow disposal was developed by Nathalie Perriera et.al [17].Implementation and benefits of introducing a CMMS into a textile manufacturing company is investigated in C.D. O'Donoghue, and J.G. Prendergast [18]. Recently; Celso et.al. [5] presented a model for preventive maintenance planning by genetic algorithms based in cost and reliability. Similarly genetic algorithms for integrated preventive maintenance planning and production scheduling for a single is presented by N. Sortrakul, H.L. Nachtmann, and C.R. Cassady [23]. (Farhad Kianfar [7] proposed a numerical method to approximate optimal production and maintenance plan in a flexible manufacturing system. Hsu-Hua Lee [9] presents a cost/benefit model for investments in inventory and preventive maintenance in an imperfect production system. This paper is an extension of the initial research on the English system used in batteries industry at General Company for liquid Battery Industries was carried out by Mukattash and Kitan [1].

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2. Experimental Measurements

Traditionally, maintenance organizations have operated in a "fire-fight" mode. "Preventing fires" has often been given a minor or causal emphasis.

The fire-fighting mode (fix it when it breaks) is called Corrective Maintenance, while the latter (fix it before it breaks) is called Preventive Maintenance (PM) as shown in Fig.A1 appendix Lindbeck and Wygant, [12] and Burton et. al. [2]. A key distinction among these three perspectives relates to the time interval between the recognition of the need to perform a maintenance activity and the time the maintenance activity is performed.

3. Evaluating Factors Scoring for Maintenance Activities

The evaluation approach of maintenance activities usually categorizes a given maintenance system by scoring its activities more often on a scale of one to four. The higher the category scores for a factor, the greater the importance of the other categories. This is usually done with the objectives of:

- Labor usage efficiency improvement.
- Unexpected breakdowns reduction.
- Downtime reduction.
- Maintenance scheduling improvement.
- Preventive maintenance program improvement, Dhavale and Otterson, [6]:

The user has the choice to eliminate some of the factors entirely, adding new factors, changing, adding or deleting pointers in a given factor and changing their scores. The user should examine critically according his firm conditions.

4. Measuring System of Maintenance Activities

The main objective for measuring and evaluating maintenance activities in a firm is to determine the followings:

- Performance level of maintenance system.
- Deviations from maintenance plan.
- Required corrective actions.

Different evaluating systems to maintenance activities have been developed in industrial countries (Ettlcin and Jahing, 1986, Mann and Coates, [16] ,(Simith [20] and Malek and Kaitan, [15]. Any firm can use an evaluating system according to nature of their industrial function. Some of these systems used on the national levels such as, The English system used in automobile industries , The American system used in engineering industries , The Egyptian system used in chemical industries, The Soviet system used in metallurgical industries , The Yugoslavian system used in mechanical industries and The English system used in batteries industry. All of these systems for measuring and evaluating maintenance activities are used to annually evaluate the efficiency of maintenance plan execution according to certain determined goals.

5. Case Study

The English system used in battery industries has been applied in the one of the Middle East companies called General Company for Liquid Battery Industries. A computer program written in visual basic was built as an evaluation system for maintenance activities in this company and the results for each factor and their pointers are compared with the standard values at "Chloride" company. It was found necessary to modify it with regard to:

- Factors and pointers for planning efficiency.
- Factors and pointers for loading efficiency.
- Factors and pointers for costs.
- Factors and pointers for productivity.

The modified approach in applying "Chloride" system is based on identifying two pointers for each factor. This modifying method depends on four parameters, which reflect the own production environment of battery Industry Company as follows:

- Size of company and the type of functional organization to production department.
- Varieties and continuity of production type.
- Work nature, time and operating environment.
- Skills, number, stability of maintenance workforce.

The actual measured values for the major (4) factors (planning, loading, costs, and productivity) depend on the determined pointers for each factor. These eight pointers represent the basic for measuring the maintenance activities. A flow chart that illustrates the algorithm steps required for measuring the efficiency of maintenance activities in the chosen company is shown in Fig.1 below.

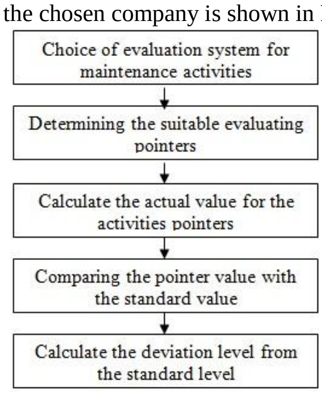

Figure 1: Flow chart of the steps of measuring maintenance activities efficiency

5.1. Planning Efficiency Factor Calculations:

5.1.1. Workforce effectiveness (LE) Pointer:

L.E = (Z-Q) / Z x R

Where:

Z= Total operation hours,

Q= Total absenteeism hours,

and

R = Workforce skillfulness average.

The calculation procedure for LE is shown in Fig. 2 below.

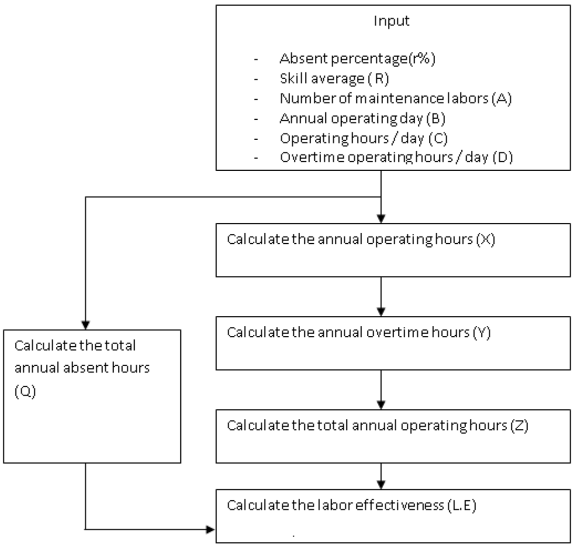

Figure 2: Calculation procedure for labor effectiveness.

5.1.2. Executed Maintenance Work/planning maintenance Work Pointer (KT):

KT = BT/AT × 100

Where:
BT = Number of actual maintenance hours,

AT = Number of planned maintenance hours.

The calculation procedure of KI for each department and KT for the overall company is shown in Fig. 3 below.

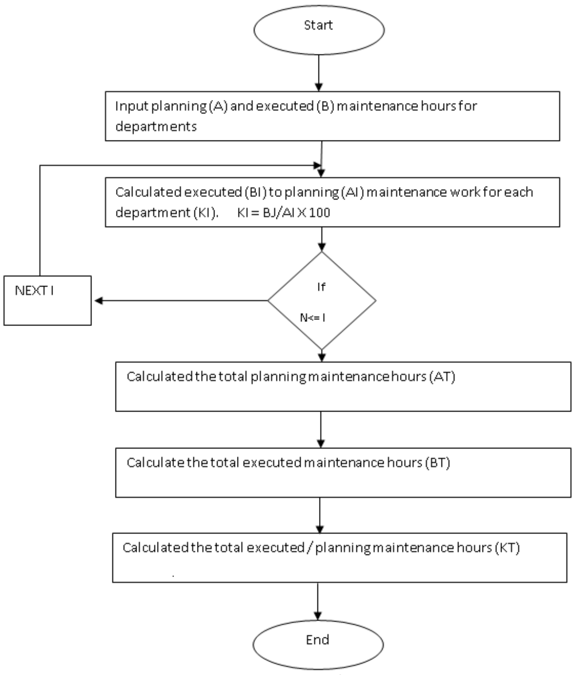

Figure 3: Calculation procedure for executed / planning maintenance hours.

5.2. Loading Efficiency Factor Calculations:

5.2.1. Total Preventive Maintenance Hours / Total Maintenance Hours Pointer (KP):

KP = PT / AT × 100

Where:

PT = Preventive maintenance hours,

AT = Total maintenance hours

5.2.2. Corrective Maintenance Hours / Total Maintenance Hours Pointer (KC):

KC = CT / AT × 100

The calculation procedure for preventive and corrective maintenance hours / total planning is shown in Fig. 4 below

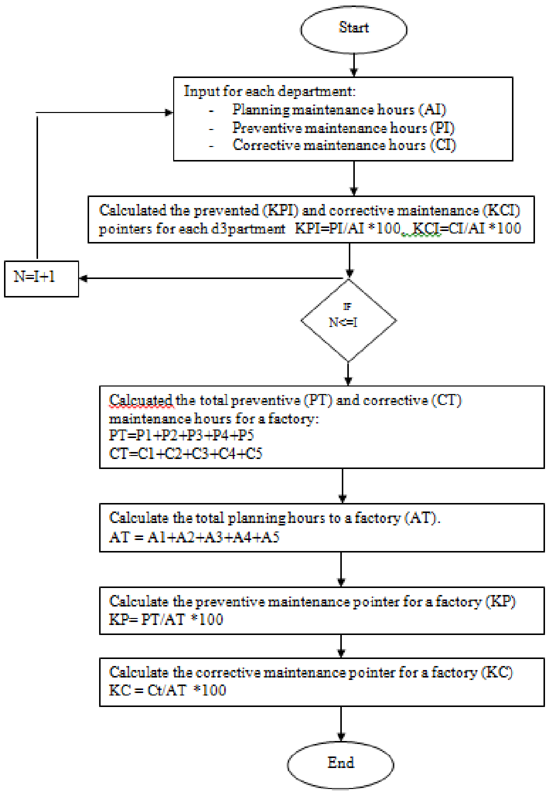

Figure 4: Calculation procedure for preventive and corrective maintenance hours / total planning maintenance hours

5.3. Costs Factor Calculations:

5.3.1. Maintenance Costs / Capital Investment pointer (KI):

$$KI = TCM / CI \times 100$$

Where:

TCM = Total maintenance cost,

CI = Capital investment

5.3.2. Direct and General Maintenance Cost / Total Maintenance Costs pointer (K2):

$$K2 = (DMC + GMC) / TMC \times 100$$

Where:

DMC = Direct Maintenance Costs,

GMC = General Maintenance Costs.

The calculation procedure of costs factor pointers is shown in Fig. 5.

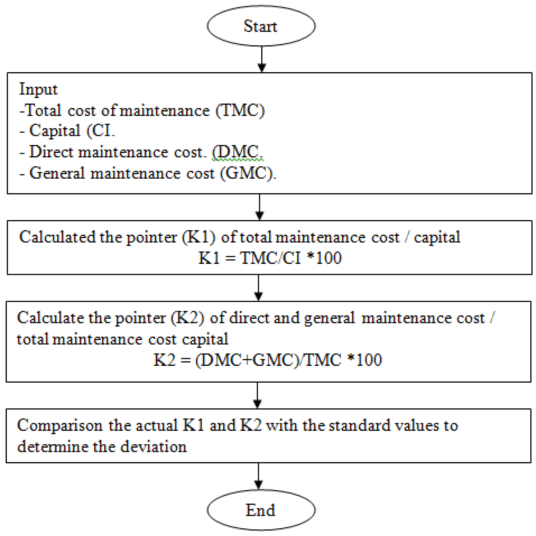

Figure 5: Calculation procedure of costs factor pointers.

5.4. Productivity Factor Calculations:

5.4.1. Labors Utility pointer (LU):

$$LU = AW / TW \times 100$$

Where:

AW = Actual Work,

TW = Total Work.

The flow chart shown in Fig. 6 depicted the steps for calculation of KI for each department and KT for the overall company.

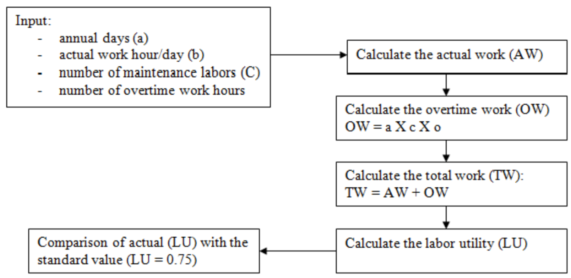

Figure 6: Calculation procedure of Labors utility (LU) pointer

5.4.2. Production Breakdown Time for Maintenance / Total Operating Time (machine-hr) Pointer (MB):

$$MB = TBhs / E$$

Where:

Bhs = Total breakdown hours,

E = total energy.

The calculation procedure of production breakdown for maintenance is shown in Fig.7 below.

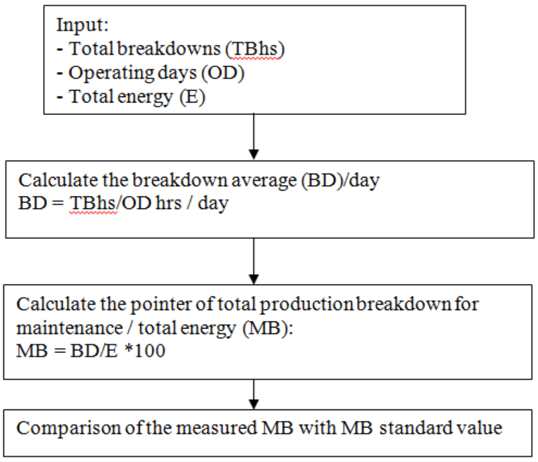

Figure 7: Calculation procedure of production breakdown for maintenance

An example of execution the algorithm steps sequencing for maintenance system evaluation (MSE) is illustrated through the different menus as shown in fig A2 appendix and figs. (8, 9, and 10) below

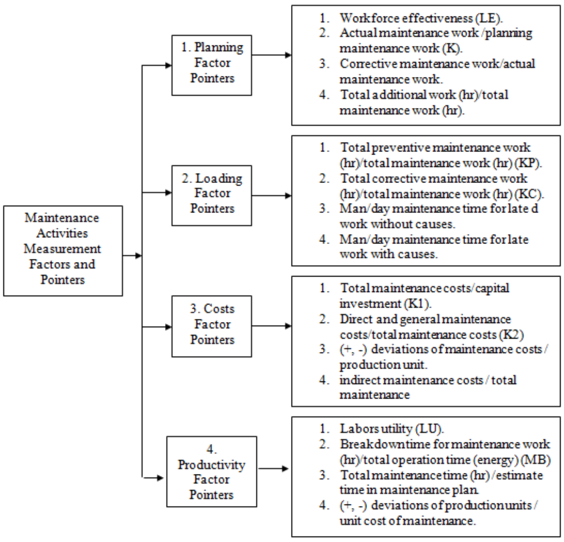

Figure 8: English system menu

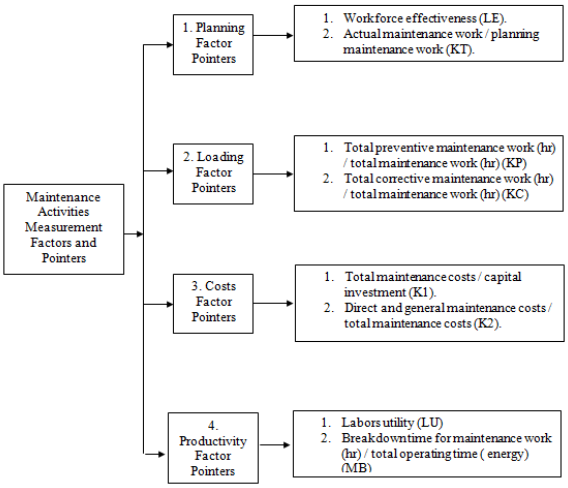

Figure 9: Selected pointers menus

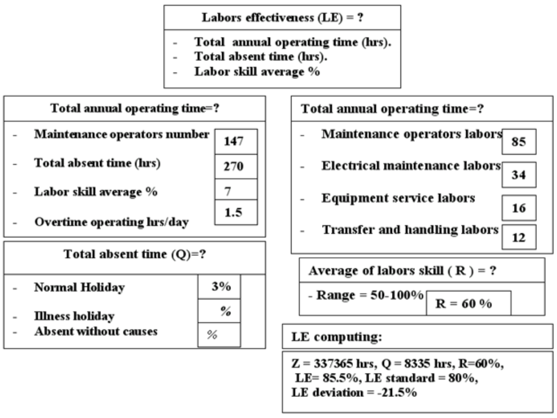

Figure 10: LE calculation menu

6. Results Analysis

The deviations of maintenance activities measurements from targeted levels resulted from comparing the actual results with standard values. These deviations for the selected factors and their pointers are illustrated in Table 1. The lack of labor effectiveness (LE) ranked as the first one as the actual value is (58.5%) while the standard value is (80%). Which means a deviation value around (58.5-80=-21.5%). The production breakdown pointer for maintenance has actual value of (7.8%) with a deviation value of (7.8-3 = 4.8%).

Table (1): Results of MES maintenance activities factors and pointers

Factors	Pointers	Pointers Values			Factors Values		
		Actual Value %	Standard Value %	Deviation	Actual Value %	Standard Value %	Deviation%
Planning	Workforce Effectiveness	58.5	80	-21.5	56	82.5	-26.5
	Actual Maintenance Work / Planned Work	53.5	85	-32			
Loading	Preventive Maintenance Hours / Total Maintenance Hours	18.5	25	-6.5	50	50	0
	Corrective Maintenance Hours/total Maintenance Hours	81.5	75	+6.5			
Costs	Total Maintenance Costs / Capital Investment	6.5	6	+6.5	38.25	45.5	-7.25
	Direct and General Maintenance Cost / Total Maintenance Costs	70	85	-15			
Productivity	Labors Utility	67	75	-8	37.4	39	-1.6
	Breakdown Time / Total Operating Time	7.8	3	+4.8			

7. Conclusion

Maintenance management may be a key strategic variable in the quest for waste that will lead eventually to strong competitive advantage. Leading companies understand the necessity for linking production planning with maintenance planning activities in order to reduce waste. Waste is inherently greater if production and maintenance plans are not linking, made poorly or not followed closely.

The knowledge that has been gained in linking production planning with maintenance planning is essential to for a proactive maintenance program. And it also essential to compressing the computer-aided evaluating system for maintenance activities. Applying the knowledge will help in reducing waste and greater productivity.

Throughout the inspection of all actual values of pointers for maintenance activities in the company, some of other conclusions are:

- Cannot give an indication of the costs, which are resulted from the production breakdown (interruptions) because of machines breakdowns on the direct cost of the product. Thus, the management doesn't take care for maintenance in relative to the size of loses because of the frequency of production breakdowns. This situation appears in deviation value (-21.5%).
- Do not reflect the machines breakdowns as a major reason to prevent execution production plan in quality and quantity. This lead the management reasoning to consider the preventive maintenance cost as additional financial and managerial load. Also it dose not give a precise assessment of and the required cost for preventive maintenance and take the corrective maintenance as an alternative. The preventive and corrective maintenance deviations reflect above management reasoning respectively (18.5-25 = -6.5%), (81.5-75 = +6.5%).
- According to the above conclusions, the necessity to consider computer – aided evaluation to maintenance activities is important. This computer system is simple in reasoning and application in short intervals (i.e. weekly, monthly) instead or beside the present systems that have long evaluating intervals (i.e. semester, annual). This short intervals computer system is active and flexible to take the corrective actions in proper position and time in relation to the degree of deviation for each evaluating pointer. It also reflects the positive state for production continuity in fewer breakdowns.

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Appendix

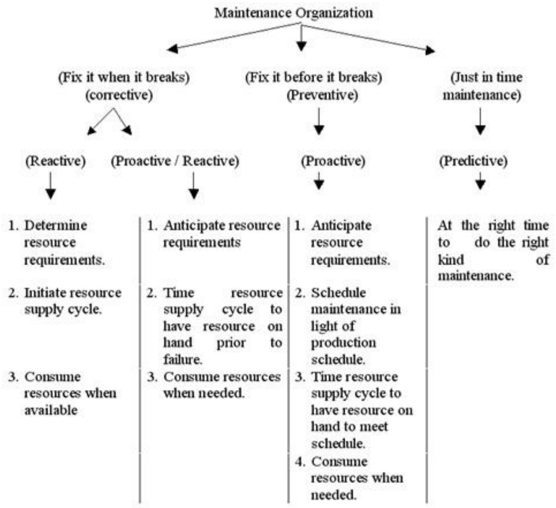

Figure A1: Maintenance Management Perspectives.

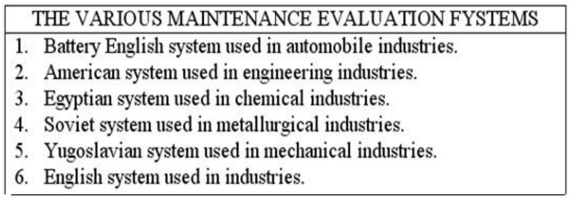

Figure A2: Main menu of the program.