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Review of Optimization Models and Techniques for Maintenance Decision Support Systems in Small and Medium Industries

Zulkifli Tahir, Anton Satria Prabuwono, M.A. Burhanuddin, Habibullah Akbar

Industrial Computing Department
Faculty of Information and Communication Technology
Technical University of Malaysia Melaka
Locked Bag 1200, Ayer Keroh,
75450 Melaka, Malaysia
{zulkifli_ra, antonsatria, burhanuddin, habibullah_ra}@utem.edu.my

The research is based on the fact that decision support is needed for maintenance process in commonly . Many maintenance functions with varieties models and techniques have been proposed for the problems. The aim of this research was to identify optimization models and techniques to conduct decision support system in small and medium (SMIs). A systematic literature review was performed relevant information. The results shown several trends in the fields area. Next, the research direction has been to develop the systems.

I. INTRODUCTION

The importance of maintenance functions for maintenance in commonly industries has growing rapidly. A researches and publications in the field maintenance models and techniques have been published to the effectiveness of maintenance process. As a part of project for maintenance decision support system in and medium industries, we need to collect the related in those areas. The specific objectives on this :

- To describe the classifications and available literature in the field of maintenance decision models and techniques.
- To identify trends in the field of maintenance decision support system.
- To suggest directions for future researches in this field.

II. MAINTENANCE TECHNIQUES

A maintenance technique is the procedure that used by maintenance management for doing their maintenance process. It is expected that the most appropriate maintenance strategy (such as predictive, preventive, or corrective) can be determined. There are many maintenance techniques have been introduced. References [1] classified various maintenance techniques from 54 papers into ten areas maintenance techniques as shown in Fig. 1.

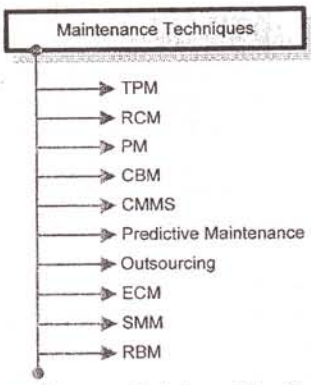

Fig. 1 Maintenance Techniques Classification [1]

Each classification and available literature of maintenance techniques has been described as follow:

A) Total Productive Maintenance (TPM): it is the maintenance theory which has been introduced by Nakajima [2] that identified maintenance activities as the five major pillars, and then, now have improved become eight pillars, consists of health and safety, education and training, autonomous maintenance, planned preventive maintenance, quality maintenance, focused improvement, support systems, and initial phase management ([3]-[15]).

B) Reliability Centered Maintenance (RCM): A set of tasks generated on the basis of a systematic evaluations that are used to develop or optimize a maintenance program. RCM incorporates decision logic to ascertain the safety and operational consequences of failures and identifies the mechanism responsible for those failures ([16]-[21]).

C) Preventive Maintenance (PM): it is an important maintenance activity. Within a maintenance organization it usually accounts for a major proportion of the total

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maintenance effort. PM may be described as the care and servicing by individual involved with maintenance to keep equipment/facilities in satisfactory operational state by providing for semantic inspection, detection, and correction of incipient failures either prior to their occurrence or prior to their development into major failure. Some of the main objectives of TPM are to: enhance capital equipment production life, reduce critical equipment breakdowns, allow better planning and scheduling of needed maintenance work, minimize production losses due to equipment failures, and promote health and safety of maintenance personnel ([8], [9], [22]-[41]).

D) *Condition Based Maintenance (CBM):* The PM service is based on some reading, measurement going beyond a predetermined limit. If the machine cannot hold a tolerance, a CBM is initialized ([42]-[48]).

E) *Computerized Maintenance Management System (CMMS):* it is one of a computer software program that 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 tracery history; and the recording of parts transactions [49]. One of the research by [50] propose decision making grid (DMG) to support the CMMS applications ([51]-[57]).

F) *Predictive Maintenance:* it is consists in deciding whether or not to maintenance a system according to its state ([58], [59]).

G) *Maintenance Outsourcing:* this refers to transferring workload to consider with the goals of getting higher quality maintenance at faster, safer and lower cost. The others goal are to reduce the number of full-time equivalents (FTEs) and concentrate organization's talent, energy and resources in to areas called core competencies ([60]-[62]).

H) *Effectiveness Centered Maintenance (ECM):* it stresses "doing the right things" instead of "doing things right". This approach focuses on system functions and customer service, and has several features that are practical to enhance the performance of maintenance practices and encompasses core concepts of quality management, TPM and RCM. The ECM approach is more comprehensive as compared with TPM and RCM. It is composed of people participation, quality improvement, and maintenance strategy development and performance measurement [63].

I) *Strategic Maintenance Management (SMM):* In the SMM approach, maintenance is viewed as a multi disciplinary activity. This approach overcomes some of the the deficiencies of RCM and TPM approaches as these do not deal with issues like operating load on the equipment and ints effect on the degradation process, long term strategic issues and outsourcing of maintenance, etc. in addition, these approaches to large extent are qualitative or at the most quantitative. The SMM approach is more quantitative, involving the use of models that integrate technician, operational aspects from business viewpoint. SMM views maintenance from a broader than that of RCM and TPM [64].

J) *Risk Based Maintenance (RBM):* RBM maintenance strategy meeting the minimization of hazard caused by equipment and a cost effective strategy [65].

III. Maintenance Optimization

Maintenance optimization is the process balance of maintenance requirement such as economic, technical or others. The goals is appropriate maintenance technique for equipment in the system and identifying the maintenance technique should be conducted best requirement, maintenance target equipment reliability, and system References [1] have presented various resources maintenance optimization models as shown in Fig. 2.

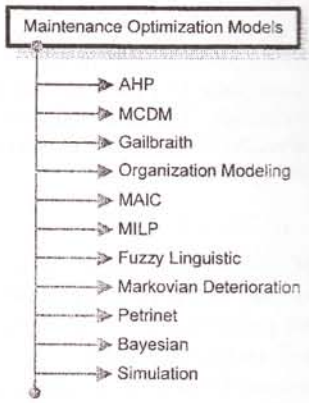

Fig. 2 Maintenance Optimization Classification [1]

Each classification and available literature of optimization models has been described as follow:

A) *Analytical Hierarchy Process (AHP):* it was Thomas L. Saaty [66] as mathematical decision model to solve complex decision making problems there are multiple objectives or criteria requires the decision makers to provide judgments the relative importance criterion for each alternative ([67], [68]).

B) *Multiple Criteria Decision Making (MCDM):* selecting between alternates is a relatively often difficult task. MCDM refers to the decision and planning problems involving multiple generally collecting requirements. The Decision (DM) one reasonable alternative from among available ones ([69], [70]).

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Galbraith: The theory believes that "the greater uncertainty of the task, the greater amount of information that must be processed between decision makers during the execution of the task to get a given level of performance". Industries can reduce uncertainty through better planning and coordination, often by rules, hierarchy, or goals [71].

Organization Modeling: References [72] reviews maintenance organization models, e.g. advanced technological model (ATM), Eindhoven University of Technology model(EUT), total quality management (TQM), Total Productive Maintenance (TPM), Reliability Centered Maintenance (RCM), model etc, and suggest maintenance can be contributor to profits by use of information technology (IT) and showed that integrated IT permits co-planning of production with maintenance.

Materially per Apparencchiature de Impiariti Chemiei (MAIC): References [73] have presented a knowledge-based decision support system, MAIC for maintenance of chemical plant.

Mixed Integer Linear Programming (MILP): It is very general framework for capturing problems with both discrete decisions and continuous variable. This includes assignment problems, control of hybrids system, piecewise-affine (PWA) system (including approximation of nonlinear system), and problems with non-convex constrains [74].

Fuzzy Linguistic: Fuzzy logic was introduced by Dr Lofti Zadeh of UC/Berkeley in 1960s as a superset of conventional or Boolean logic that has been extended to handle the concepts of partial truth – truth values between "completely true" and "completely false". It was described as a means to model the uncertainty of natural language. Zadeh stated that rather than regarding fuzzy theory as a single theory, we should regard the process of "fuzzyfication" as a methodology to generalize any specific theory from crisp or discrete to a continuous or fuzzy form [75]. By the term "fuzziness" Zadeh meant classes in which there is no sharp transition from membership [76].

Markovian Deterioration: Markovian deterioration is a mathematical model for the random evolution of a memoryless system. Often the property of being 'memoryless' is expressed such that conditional on the present state of the system, it's future and past are independent ([77]-[80]).

Petrinet Petri nets, it is one of several mathematical modeling languages for the description of discrete distributed system. A Petri net is a directed bipartite graph, in which the nodes represent transitions (i.e. discrete events that may occur), places (i.e. conditions), and directed arch (that describe which places are pre – and/or post conditions for which transitions)[81].

Bayesian: Bayesian statistic is based on Bayes' rule or conditional probability. It is well known that probability of events A and B both occurring can be written as the probability of A occurring multiplied by probability of B occurring given that A has occurred ([82], [83]). This is written as:

$$P(A \text{ and } B) = P(A)\, P(B/A)$$

K) *Simulation:* [84] and [85] use the Monte Carlo simulation to determine optimum maintenance policy and for modeling on continuously monitored systems. [86] has used simulation model to reduce maintenance and inventory cost for a manufacturing system with stochastic item failure, replacement and order lead times. [87] demonstrates application of simulation models to evaluate maintenance policies for an automated production line in a steel rolling mill.

IV. Trends Identification

After a brief description of classification in maintenance optimization models and techniques, we have identified several trends that related in the field of maintenance decision support systems, each of which have been described as follow:

1) From all described publications, there are limited models have been implemented in industrial maintenance process. The data problems and the gap between theories and practice have always become the reason.
2) It seems a lot of maintenance optimization models and techniques have been published for this area. Various simulating tools and mathematical models have been attempted. Although the improvement of IT (both soft and Hardware) can support to easy develop of the system with low cost and systematic modules, it is limited work has directed toward developing into operational applications such as computerized system or DSS. It can be said that the impact of decision making within a maintenance organization has so far been limited.
3) Some of the publications have designed the integration of existing maintenance optimization models and techniques such as DMG, ECM, SMM and RBM. It can be notice that a new potential research have existed to implement them in the real CMMS or DSS applications.
4) Much design of CMMSs is as a device for analysis and coordination to storehouse the maintenance information, such as a PM tool and a maintenance work planning tool. However, less of them have embedded with decision support modules to be linked in the actual industrial maintenance process.

V. Research Direction and Activities

The direction is highlighting to emerging trends that have been identified. The futures researchers can conduct the maintenance decision support system with consider the

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finding trends. The following step is suggested to conduct the systems.

1) *Choosing the maintenance techniques:* it is the fundamental steps that we must concern to follow in industrial maintenance process. There are ten techniques that we can choose from this papers description. Each of them have specific characteristic. We can choose the most appropriate techniques that can be implemented in the real industrial maintenance process.
2) *Data Analysis:* it is a fundamental issue in optimizing maintenance decision making. The decision based on incorrect information may be useless or harmful. Some times data is seems to be plentiful, by may not be of quality of the quality expected.
3) *Maintenance information system interface:* One of popular interfaces in industries is CMMS. It is mainly serves as databases. The maintenance data in CMMS is the most important information to help maintenance department making the right decision for getting the right maintenance strategies. Fig. 3 is described by [88] as prototype to get decision out from maintenance data in CMMS industries.

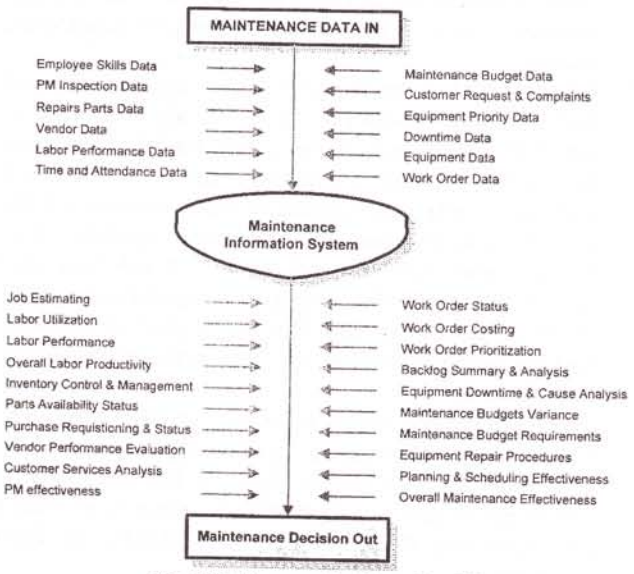

Fig. 3 Maintenance Decisions Out [88]

4) *Choosing optimization models:* It seems a lot of maintenance optimization models with various simulating tools and mathematical models have been proposed in our area. Choosing the right one that match with our data measurement is one step to do. A true maintenance optimization process continually monitors and optimizes the current maintenance program to improve its overall efficiency and effectiveness.
5) *Decision out:* In the process of decision making, decision makers combine different types of data (i.e. internal and external data) and knowledge (i.e. tacit and explicit knowledge) available in various forms in the industries or its external environment. Decision can be conduct from identify the related data measurement with decision making models.

VI. Conclusions

We have reported the ongoing research project aimed to conduct maintenance decision support systems for small and medium industries. The research is developed with identifying the appropriate literature from published maintenance optimization models and techniques. The results have shown the trends that related in the fields area. Next, those trends will be definitely giving benefit for assist the research project team to develop the system.

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