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Computer-aided maintenance management systems selection based on a fuzzy AHP approach

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ABSTRACT

Computerized maintenance management systems (CMMS) are common in today's industries. CMMS can bring a large number of benefits, which include increased productivity, reduced costs, and effective utilization of the assets in any manufacturing and service producer. The list of CMMS that are available in the market has grown very rapidly during the last years. When purchasing a system, one that suits the specific needs and objectives of the company's maintenance operations should be preferred. Several selection methods were proposed in literature. Up to now, no article has considered ambiguity and uncertainty factors when selecting effective CMMS. In addition, CMMS selection decisions involve the simultaneous consideration of multiple criteria, including tangible and intangible factors; prioritizing these factors can be a great challenge and a complex task. Therefore, no attempt has been made to incorporate fuzziness into multicriteria decision-making in the area of CMMS selection. This work proposes a fuzzy–based methodology for comparative evaluation of a number of CMMS alternatives. The proposal is based on the well-known multicriteria decision method called Analytical Hierarchy Process (AHP) with triangular numbers. An example is given to illustrate the proposed methodology. Finally, a software prototype for implementing this method was implemented. To illustrate and validate the proposed approach and the software prototype developed some details are presented and discussed.

1. Introduction

The increase in automation and the reduction in inventories in industries have clearly put more pressure on the maintenance systems. Any disruption to production flows becomes costly and critical. This makes the maintenance function relevant to operations management to keep organizations productive and profitable along time. Therefore, computerized maintenance management systems (CMMS) are becoming increasingly important in the last few years. Using CMMS is a highly relevant issue in a production environment where the number of critical equipment is high or where the need for maintenance resources management is significant. A large variety of computer software is available on the market for maintenance management. It is not surprising that many companies have been disappointed with the results of their implemented CMMS. An extensive survey [1] reported that there is a paradox in CMMS selection and implementations. According to this survey, 62% of the respondents changed their maintenance work process to fit the CMMS characteristics and 66% customized the CMMS to fit the work process. These numbers reflect that the selection of the most suitable CMMS is a crucial task to eliminate all these problems and difficulties.

Selection and evaluation of a CMMS is a very difficult and complex task. The following five factors can be identified as the main causes of this complexity:

(1) The tremendous number of software products available in the market.
(2) The continual advancements and improvements in information technology (IT).
(3) The existence of incompatibilities between various hardware and software systems.
(4) The functional dissimilarities are difficult to evaluate among software packages.
(5) The users lack the technical knowledge and experience for software selection decision making.

As it was previously commented, decision making in the field of maintenance management software selection has become more complex due to a large number of software products in the market, ongoing improvements in information technology, and multiple and sometimes conflicting objectives. Some methodologies and frameworks for CMMS selection and evaluation have been developed. Raouf et al. [2] presented an instrument to select suitable system using a comparative strategy and the concept of relative importance among a set of required functions in accordance to

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the intended use of the CMMS. More recently, Carnero and Noves [3] presented an evaluation system for the selection of computerized maintenance management software in industrial plants using multicriteria methods. Braglia et al. [4] proposed a methodology to perform a selection of the best suited CMMS within process industries. To improve the effectiveness of the methodology proposed by Braglia et al. [4], they combined AHP with a sensitivity analysis. Those evaluation systems use the AHP method in its basic version (crisp numbers). Up to now, no article has considered ambiguity and uncertainty factors when selecting effective CMMS. In addition, software selection decisions involve the simultaneous consideration of multiple criteria, including tangible and intangible factors; prioritizing these factors can be a great challenge and a complex task. Labib [5] published an investigation of the characteristics of CMMS, identified their deficiencies. In addition, Labib proposed a model to aid the decision analysis capability in CMMS under selection [5].

These factors arise as the main motivation of this research work, which is aimed at how to select an appropriate CMMS facing the strategic and operational requirements of the organization using a multicriteria decision method incorporating concepts of uncertainty and uncompleted information.

In other words, this study proposes a comprehensive CMMS selection framework in which the objective hierarchy is constructed and the appropriate attributes are specified using fuzzy numbers to provide guidance for CMSS evaluation. The analytic hierarchy process (AHP) method [6] and fuzzy numbers are applied for dealing with the ambiguities involved in the assessment of CMMS alternatives and relative importance weightings of attributes.

2. Multicriteria decision model

The analytic hierarchy process (AHP) developed by Saaty [6] is a decision-making tool that can handle unstructured or semi structured decisions with multiperson and multicriteria inputs. It is a decision-rule model that relaxes the measurement of related factors to subjective managerial inputs on multiple criteria. AHP has several advantages, including its acceptance of inconsistencies in managerial judgments/perceptions and its user friendliness because users may directly input judgment data directly without the requirement of mathematical knowledge. It also allows users to structure complex problems in the form of a hierarchy or a set of integrated levels. One of the main advantages of this method is the relative ease with which it handles multiple criteria. In addition to this, AHP is easier to understand and it can effectively handle both qualitative and quantitative data. The use of AHP does not involve cumbersome mathematics. AHP involves the principles of decomposition, pair wise comparisons, and priority vector generation and synthesis. The power of AHP has been validated by empirical application in diverse areas such as healthcare [7], planning [8], mining [9], project management [10], missile systems [11], new product development [12] and manufacturing [13]. In addition AHP has been used in making decisions that involve ranking, selection, evaluation, and selection of machines and IT based systems [14–16].

To construct the hierarchy of objectives and attributes of a generic CMMS an extended review of the related literature was conducted. This review focused on CMMS selection and, on general-purpose software selection problem. Two works arise as the most significant ones to the goal pursuit by our approach.

Cato and Mobley [17] listed some activities which constitute subsystems or modules of a generic CMMS: equipment/asset records creation and maintenance, asset bills of materials creation and maintenance, asset and work order history, inventory control, work order creation and control, preventive maintenance planning and scheduling, human resources, purchasing and receiving, invoices matching, and, reporting.

Considering Carnero and Novés' [3] opinion the key functions for any CMMS are:

- Easy work management.
- Planning function.
- Scheduling function.
- Budget/cost function.
- Spares management.
- Key performance indicators.

More recently, Bradshaw [18] listed the basic capabilities of a CMMS. They are: assets database, maintenance activities records, corrective maintenance, preventive maintenance and maintenance work scheduling and control. Besides, the same author incorporates what he called improved CMMS capabilities; they are integration and interfacing capabilities and, communication, data collection and transfer.

Wei et al. [19] distinguish two categories of attributes to select an enterprise resource planning system, including system factors and vendor factors. Among the subcriteria related to the system factor they suggest the total cost, implementation time, functionality, user friendliness, flexibility and reliability. On the other hand, the subcriteria related to the vendor factor they used vendor reputation, technical capability and supplying ongoing service.

These characteristics lead the authors to propose the hierarchy used in the evaluation approach. Table 1 presents the detailed description of the used attributes in the fuzzy AHP model.

Since all organizations are different, it is very important to perform a previous identification of maintenance management (MM) IT requirements. Kans [20] presents a formal method for the identification of MM IT requirements. Accordingly Kans' work, the choice of technical features of MMIT is dependent upon the needs and characteristics of the specific organization.

Once the IT requirements identification is completed, a series of candidate software systems will arise as a result of the requirements identification phase. Those candidates software systems will have to be classified or ranked using a MCDM with the participation of domain (maintenance management) experts. For that objective, a fuzzy AHP approach was developed and applied to the problem of CMMS selection. The next section discusses the fuzzy-AHP methodology.

3. Fuzzy AHP methodology

The fuzzy AHP methodology extends Saaty's AHP by combining with fuzzy set theory. In the fuzzy AHP, fuzzy ratio scales are used to indicate the relative strength of the factors in the corresponding criteria. Therefore, a fuzzy judgment matrix can be constructed. The final scores of alternatives are also represented by fuzzy numbers. The optimum alternative is obtained by ranking the fuzzy numbers using special algebra operators.

The next three steps can summarize the procedure of applying fuzzy AHP:

i. Construction of a hierarchical structure for the problem to be solved.
ii. Establish the fuzzy judgment matrix and a fuzzy weight vector.
iii. Rank all alternatives and select the optimal one.

Three levels compose the hierarchy of the evaluation system. The suggested hierarchy is depicted in Fig. 1. The first level is the