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A hybrid MCDM methodology for ERP selection problem with interacting criteria

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ABSTRACT

An enterprise resource planning (ERP) system is an information system to plan and integrate all of an enterprise's subsystems including purchase, production, sales and finance. Adopting such a comprehensive framework may result in the great savings in both costs and man hours. This research explores the application of a hybrid multicriteria decision making (MCDM) procedure for the evaluation of various ERP alternatives. The proposed evaluation framework integrates three methodologies: Analytic Network Process (ANP), Choquet integral (CI) and Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH). ANP produces the priorities of alternatives with respect to the interdependent evaluation criteria. The conjunctive or disjunctive behaviors between criteria are determined using MACBETH and CI. Numerical application of the proposed methodology is implemented on the decision making problem of a firm that faces with four ERP projects. The final ranking is compared to the one obtained by ignoring the interactions among criteria. The results demonstrate that the ignorance of the interactions may lead to erroneous decisions.

1. Introduction

Due to severe market competition, companies have directed to consider alternative business environments in order to reduce total cost, maximize return on investment, shorten lead times and be more responsive to customer requirements. An enterprise resource planning (ERP) system can be considered as a solution for inefficient business processes. Organizations think about purchasing it when they deal with a number of complex and interrelated business troubles, such as achieving company's financial goals, managing and streamlining the company's operational processes, better forecasting features or obtaining the benefits of improved information management by reducing data duplication. An ERP system typically implements a common enterprise-wide database together with a range of application modules [13]. It standardizes processes and stores information as well as recalls that data when it is required in real time environment. Implementing an ERP system may be costly and time-consuming. Companies spend billions of dollars and use numerous amounts of man-hours for installing elaborate ERP software systems. However, the benefits of a successful ERP project are worthwhile.

The offered ERP software packages cannot provide a once-for-all business model for every process of all industries. In other words, no single ERP packaged software can meet all company functionalities or all special business requirements [33]. Thus, companies must choose a flexible ERP system that is responsive to customer requirements. The major reason for ERP implementation failures is stated as the inappropriate system selection [13,22]. An inappropriate selection process can significantly affect not only the implementation but also the performance of the company [9]. Therefore, the importance of selecting a suitable ERP system cannot be overemphasized [19].

This paper introduces a hybrid multicriteria decision making (MCDM) model for ERP selection based on Analytic Network Process (ANP), Choquet Integral (CI) and Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH). MCDM refers to find the best opinion from all of the feasible alternatives in the presence of multiple, usually conflicting, decision criteria. It is a branch of a general class of operations research models that deals with the decision making problems under the presence of a number of decision making alternatives described by their attributes [8]. Priority based, outranking, distance-based and mixed methods could be considered as the primary classes of the current methods [26]. One of the most outstanding MCDM approaches is ANP which is a generalization of one of the most known MCDM methodologies: Analytic Hierarchy Process (AHP) [30]. While AHP represents a framework with a unidirectional hierarchical relationship, ANP allows for complex interrelationships among decision levels and criteria. ANP is used in many decision support systems of various types. Verdecho et al. [32], have provided a methodology based on ANP to prioritize and manage inter-enterprise performance at both the strategic and the process level. Another research has explored the application of ANP approach for the evaluation of R&D projects that are elements of programs with heterogeneous objectives [21]. Although there are various methods, such as mathematical programming, MCDM

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analysis or scoring, which is applied to the ERP software selection, we focus on studies including MCDM analysis. Wei et al. [33] have introduced their selection framework that is based on AHP method. Erensal and Albayrak [14] have suggested AHP to effectively enhance adoption of macroergonomics and to improve management decision performance in measuring and comparing the overall performance of different management styles based on macroergonomical criteria. The most similar work to our proposed framework is the work of Yazgan et al. [34]. However, they have designed an artificial neural network model and trained with using ANP results in order to calculate ERP software priorities.

In our paper, we have categorized ERP selection criteria into three main sets: vendor related criteria (VRC), customer related criteria (CRC), and software related criteria (SRC). Each one consists of its own sub-criteria set. Since these criteria and sub-criteria have both inner and outer dependencies, we have made use of the ANP to determine these dependencies and relative priorities of all criteria. MACBETH is both an approach and a set of techniques that have the goal of providing an overall ordering of options, and that aid on the construction of interval numerical scales based on qualitative (non-numerical) pairwise comparison judgments [4,12].

In this research, we have used CI to determine conjunctive or disjunctive behaviors between criteria and integrated MACBETH in CI in order to define the parameters of CI. The last phase of the proposed methodology involves ranking the given ERP alternatives according to their final performance scores. We have shown the feasibility of the framework on the decision making problem of a company that needs to evaluate four ERP software alternatives and select the most suitable one according to its requirements. Furthermore, we have obtained another ranking by using the same evaluation values; however this time we have ignored the interactions among criteria. The comparison has shown that the final ranking may change dramatically with the ignorance of the interactions and therefore it may lead us to erroneous decisions.

The remaining part of the paper is organized as follows: Section 2 describes the methodologies that constitute the proposed framework. The steps and details of the proposed decision support framework are introduced in Section 3. The implementation into the ERP selection problem is presented in Section 4. Finally, Section 5 gives the concluding remarks of the study.

2. Preliminaries

In this section, three methodologies underlying the proposed framework (ANP, CI and MACBETH) along with their integration will be presented.

2.1. Analytic Network Process (ANP)

ANP, as well as AHP, incorporates both qualitative and quantitative approaches to a decision problem [10]. It is also capable of capturing the tangible and intangible aspects of relative criteria that have some bearing on the decision making process [30]. AHP is limited to relatively static and unidirectional interactions with little feedback among decision components and alternatives [20]. However, many real life decision problems cannot be structured as a hierarchy because of the interactions and dependence among criteria. Therefore, the hierarchy becomes more like a network. On this context, ANP and its supermatrix technique can be considered as an extension of AHP that can handle a more complex decision structure as the ANP framework has the flexibility to consider more complex interrelationships (outer dependence) among different elements [30,31]. Hence, ANP is very useful in these kinds of situations providing a general framework without the assumptions of independence of higher-level elements from lower ones, or independence on the same level.

ANP framework has three basic features which are useful in multicriteria decision making problems:

- Define the goal and criteria (and sub-criteria),
- Determine the interdependencies and the network,
- Build the supermatrix and synthesize.

In this approach, comparison matrices, prioritization and the weights while considering the interdependencies are formed between various attributes of each level with the scale of 1–9 suggested by Saaty [29]. Also the consistencies of the pairwise comparisons, made by the experts or decision makers (DMs), have to be checked in order to make the necessary changes, if there is any inconsistency above the allowed limit. Once the pairwise comparison matrices are formed, weight vectors for all the matrices are calculated. The concept of supermatrix is used to obtain the composite weights that overcome the existing interrelationships. The synthesizing step is to rate the alternatives according to all the criteria, compute the overall score for the alternatives and make the final decision as to choose the best alternative or to obtain the final ranking of the alternatives.

2.2. Choquet Integral (CI)

The CI, which has been introduced in the fuzzy measure community by Murofushi and Sugeno [25] is a fuzzy integral proposed by Choquet [11] and considers the interactions between k out of n criteria of the problem, which is called the k-additivity property. Basic notations and definitions on the CI can be analyzed in Appendix A. In this research, 2-additive CI is used.

Letting t_i, $i=1,\ldots,n$ be the scores on the criteria, by using only the interaction index, it is possible to express CI in the case of 2-additive measures as follows [15]:

$$C_\mu(t_1,\ldots,t_n)=\sum_{I_{ij}>0}\left(t_i\wedge t_j\right)I_{ij}+\sum_{I_{ij}<0}\left(t_i\vee t_j\right)\left|I_{ij}\right|+\sum_{i=1}^{n}t_i\left(\varphi_i-\frac{1}{2}\sum_{j\neq i}\left|I_{ij}\right|\right)\quad \text{with } \varphi_i-\frac{1}{2}\sum_{j\neq i}\left|I_{ij}\right|\geq 0,\forall_i=1,\ldots n \tag{1}$$

Here, φ_i represents the relative importance of criterion i with $\sum_{i=1}^{n}\varphi_i=1$ and I_{ij}, defined in the interval $[-1;1]$, is the interaction value between criteria i and j. Appendix B presents the definitions.

Three cases may be observed for interaction value:

- Positive values of I_{ij} implies a conjunctive behavior between criteria i and j. i.e. simultaneous satisfaction of both criteria is significant for the global score.
- Negative values of I_{ij} implies a disjunctive behavior between criteria i and j. i.e. the satisfaction of either one is sufficient to have a significant effect on the global score.
- If I_{ij} is null, then there is no interaction between criteria i and j. If for all pairs of criteria, I_{ij} are null then the φ_i value acts as a weight vector in a weighted arithmetic mean. This represents the linear part of CI.

The use of CI will be demonstrated on a simple example from Saad et al.'s [28] work. Suppose we were to consider three students, A, B, and C, with respect to three subjects, mathematics, physics and literature in a school that is more scientifically oriented. Hence, the weights for these three subjects may be 3, 3 and 2, respectively. In that case, using weighted sum method and marks given on a scale from 0 to 20, the average for these students are calculated and given in Table 1.

However, if one desires to favor well equilibrated students without weak points, the weighted sum may not be the best suited method to use since student A, although having a considerable weakness in literature has been considered better than student C, who has no