An ERP System Selection Model with Project Management Viewpoint – A Fuzzy Multi-Criteria Decision-Making Approach

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ABSTRACT

Selecting an adequate enterprise resource planning (ERP) system for the organization is one of the crucial issues in an ERP project. This study proposes a three-phase ERP selection systematic framework which introduces in two principle issues: the McCall software quality model with project management viewpoint and the quantitative analysis of fuzzy analytic hierarchy process (FAHP).

In this FAHP model, there are 19 criteria sifted out and a real-world practical case is used to illustrate the application of the framework. We find out the ‘cost’ is significantly important of all factors in this ERP project. We also find ‘correctness’ is the most important criteria among the software quality factor of ERP software.

Keywords: enterprise resource planning (ERP) system, project management, McCall software quality model, multi-criteria decision-making (MCDM), fuzzy analytic hierarchy process (FAHP).

1. INTRODUCTION

Enterprise Resource Planning (ERP) system which makes business process more efficiency and business management more simplified is one of the most important Information System (IS) to organizations. During the late 1980s and early 1990s, computer hardware and software capability continued to improve. Business worked to improve their efficiency and reduce their lead time to customer. This often called for faster and better communication, improved methods for custom-configuring of products, and promising delivery schedules with better accuracy. Software companies developed many standalone applications for product data management, detailed execution system support, final assembly configurations, and many other areas of business decision support. These decision support system have been incorporated, and resulting in what is referred to as an ERP system. But defining ERP is still difficult because there are many variations of the term within the manufacturing literature (Kapp, 2001). The Association for Operations Management (APICS) offers a traditional definition of an ERP system. The APICS dictionary, 9th edition, defines ERP as “a method for effective planning, and control for all resources needed to take, make, ship and account for customer orders in a manufacturing, distribution and service company (APICS Dictionary, 1998).”

Wognum et al. (2004) indicated that when organizations implement such large like ERP systems should regard as a project implementing and devote full participation in it. Besides, owing to the complexity of the business environment, the limitations in available resources and the diversity of ERP alternatives, ERP system selection is tedious and time consuming (Wei et al., 2005). Therefore, ERP system selection is crucial in the early phase of an ERP implementation project.

This study proposes a systematic framework to select ERP system. The comprehensive framework is a three-phase approach which introduces in two main points. One is the adopting of the McCall software quality model which is extracted from project management essentials, and use the factors of McCall software quality model to be some of the ERP selection criteria. Another main point is applying fuzzy analytic hierarchy process (FAHP) to evaluate ERP system alternatives. An empirical case of a college in Taiwan is demonstrated the practical viability of our framework.

2. LITERATURE REVIEW

The number of studies have been explored various methods either qualitative or quantitative to score, rank,
optimize and multi-criteria decision-making (MCDM) analysis the ERP system or other information technology (IT) system selection problem. Some companies seek the financial approach to evaluate such systems (Farbey et al., 1992, Han, 2004). In qualitative method, Verville and Halingten (2003) suggested a six-stage model to evaluate ERP software. Scott and Kaindl (2000) also proposed a conceptual model for ERP package enhancement. Lin (2002) and Luo and Strong (2004) even introduced ERP evaluation frameworks into universities of education field.

Academic literatures of quantitative method were more often been published. Buss (1983) presented a method in the early periods of IT projects. Dissimilar to Rao (2000) who evaluated ERP software package by using decision tree, Kumar et al. (2002) applied basic statistics in an ERP selection case. Mathematical optimization methods such as goal programming, 0-1 binary programming and non-linear programming are also widespread been used in the same issue (Santhanam and Kyparisis, 1995, 1996, Lee and Kim, 2000, Talluri, 2000). Owing to the essence of IT system selection problem is a MCDM process, a number of papers adopted analytic hierarchy process (AHP) to be the analytical tool (Schniderjans and Wilson, 1991, Wei et al., 2005).

Frequently, human judgments are often ambiguous and cannot estimate his/her preference with a crisp numerical value (Herrera and Herrera-Viedma, 2000). Fuzzy set theory is developed for solving problems in which description of activities and observations are imprecise, vague and uncertain. Therefore, there were lots of fuzzy theory related studies both in theoretical and practical (Tzeng and Kuo, 1995, Tzeng et al., 1996). Furthermore, Buckley (1985) incorporated the fuzzy set theory into the traditional AHP. Thus, FAHP were suitable to solve the real-world MCDM problems (Buyukozkan et al., 2004, Huang and Wu, 2005). In reality, selecting a suitable ERP project involves multiple factors, and evaluation ratings under various attributes are frequently assessed in linguistic terms, ‘high’, ‘poor’, among others. Thus, a fuzzy MADM method is very useful in integrating various linguistic assessments and weights to evaluate ERP alternatives (Wei and Wang, 2004).

Implementation of ERP system is such large and time-consuming, it should be regard as a project implementing. Unfortunately, rare researches had involved project management viewpoint in ERP system selection. According to the project definition of Kerzner (2001), there are three most important parts including cost, time and especially performance/technology. But even Badri et al. (2001) lead project criteria including benefits, cost, risk, performance and time constraint into IT selection problem, they didn’t detailed define the most important essence of a project, that is the “performance/technology”. Consequently, we introduce the McCall software quality factors (McCall et al., 1977) to be part of the performance/technology criteria in ERP project.

ERP system selection is a fuzzy MCDM problem, and should be involved the project management viewpoint. There were two studies have adopted AHP and FAHP, respectively, to solve the ERP selection problem (Wei and Wang, 2004, Wei et al., 2005). However, these studies did not involve software quality model to interpret the performance factor in an ERP project. Both crucial issues are integrated in this study by adopting the McCall software quality model and applying FAHP evaluation method. Therefore, our three-phase comprehensive framework facilitates group fuzzy MCDM process in ERP software selection problems.

3. THREE-PHASE MCDM FRAMEWORK FOR SELECTING ADEQUATE ERP SOFTWARE PACKAGE SYSTEM

This section presents a MCDM framework which is containing three phases. A stepwise progress is readily described as follows:

Phase 1 (Identification): Characteristic identification and criteria establishment
Phase 2 (Searching): Alternatives searching for feasible solutions
Phase 3 (Analyzing): Selecting the most adequate alternative by using FAHP

Fig. 1 shows the progress of the framework. The details of each stage are presented below.

3.1 Characteristic Identification and Criteria Establishment (Identification phase)

In this phase, project team is firstly formed and project management viewpoint is involved to identify the basic characteristic of project management. Kerzner (2001) figured that the objective of project management is designed to manage or control company resources on a given activity, within time, within cost and within performance (Fig. 2). The most important essence “performance/technology” is the foundation of three, and is laying on the triangle’s bottom.

Because of different industries or organizations keep different properties, performance is not uniform in various ERP projects. Besides, the performance identification is usually difficult and often cannot clearly express.
by project participator. Thus, we adopt McCall software quality model to interpret the fundamental performance in ERP software selection project. McCall software quality model includes a useful categorization of factors that affect software quality. These software quality factors, shown in Fig. 3, focus on three important aspects of a software product: its operational characteristics, its ability to undergo change, and its adaptability to new environments.

Referring to the factors noted in Fig. 3, McCall and his colleagues provide the following descriptions (Pressman, 2001):

- **Correctness**: The extent to which a program satisfies its specification and fulfills the customer’s mission objectives.
- **Reliability**: The extent to which a program can be expected to perform its intended function with required precision.
- **Efficiency**: The amount of computing resources and code required by a program to perform its function.
- **Integrity**: Extent to which access to software or data by unauthorized persons can be controlled.
- **Usability**: Effort required to learn, operate, prepare input, and interpret output of a program.
- **Maintainability**: Effort required to locate and fix an error in a program.
- **Flexibility**: Effort required to modify an operational program.
- **Testability**: Effort required to test a program to ensure that it performs its intended function.
- **Portability**: Effort required to transfer the program from one hardware and/or software system environment to another.
- **Reusability**: Extent to which a program or parts of a program can be reused in other applications - related to the packaging and scope of the functions that the program performs.
- **Interoperability**: Effort required to couple one system to another.

Once the fundamental performance are well defined, distinctive performance could be further considered for ERP selection project which is implementing by each organize respectively. Finally, the remaining two issues of project management, time and cost, are entered to establish the complete criteria structure.

### 3.2 Alternatives Searching for Feasible Solutions (Searching phase)

The objective of this phase is searching feasible ERP software packages. We suggest an elimination method to exclude unqualified ERP systems. Under three constraints of project management, project team is easier to sequentially eliminate unqualified ERP systems, and feasible alternatives are automatically appeared. Finally, the AHP hierarchy is completely constructed.

### 3.3 Selecting the Most Adequate Alternative by Using FAHP (Analyzing phase)

Lastly, analyzing process of ISA is selecting the most adequate alternative of all candidates. In terms of the benefits as mentioned above of FAHP, the analyzing results of ISA framework are more accurate and accelerated. FAHP has a existent sequential process, a step-wise procedure summarizing by Huang and Wu (2005) is presented below.

**Step 1**: Create the hierarchies (the step is well defined in sections 3.1 and 3.2 as above)

According to the problem characteristics, to decompose each attribute and build up the hierarchy structure, the 0th layer represents the ultimate goal; the 1st layer represents the importance decision criteria that affect the ultimate goal; the 2nd layer represents the important sub criteria of the 1st layer, and so on. The last layer represents the alternate choices of the feasible solutions.
Step 2: Create fuzzy pairwise comparison matrix
According to the layer structure built in Step 1, the decision importance criteria converted into the semantic format were used to design polling questionnaires. The next phase was to convert the results of the questionnaire into fuzzy pairwise comparison matrix by using Saaty’s 9 scales (Saaty, 1980).

Step 3: Group combination
After creating the fuzzy pairwise comparison matrix, the geometric mean of each criteria in the matrix was calculated as Buckley suggested (Buckley, 1985).

\[
\tilde{M} = \left(\frac{1}{N}\right) \oplus (\tilde{M}_{ij}^{1} \oplus \tilde{M}_{ij}^{2} \oplus \ldots \oplus \tilde{M}_{ij}^{N})
\]

\(\tilde{M}_{ij}:\) Integrate Trigonometric Fuzzy Number
\(\tilde{M}_{ij}^{N}:\) the ith to the jth criteria pair comparison value by the Expert N
N: total number of experts

Step 4: Build up the fuzzy positive reciprocal matrix
After Step 3, obtaining the final calculated fuzzy numbers for each layer could form the Fuzzy Positive Reciprocal Matrix.

\[
M = \left[\tilde{M}_{ij}\right]
\]

M: Fuzzy Positive Reciprocal Matrix

\[
\tilde{M}_{ij} = (L_{ij}, C_{ij}, R_{ij})
\]

\(L_{ij}:\) the left value, in the triangular function, of the experts’ opinions of the jth evaluation principle under the ith indicator
\(C_{ij}:\) the central value, in the triangular function, of the experts’ opinions of the jth evaluation principle under the ith indicator
\(R_{ij}:\) the right value, in the triangular function, of the experts’ opinions of the jth evaluation principle under the ith indicator

\[
\tilde{M}_{ij} = 1/ \tilde{M}_{ij}
\]

Step 5: Calculate the key factors’ fuzzy weights
The formula is suggested by Buckley’s Fuzzy AHP model and defined below.

\[
\tilde{Z}_{i} = (\tilde{a}_{1} \otimes \ldots \otimes \tilde{a}_{n})^{1/n}, \quad \forall i = 1, 2, \ldots, n
\]

\[
\tilde{\omega} = \tilde{Z}_{i} \otimes (\tilde{Z}_{1} \otimes \ldots \otimes \tilde{Z}_{n})^{-1}
\]

\(\tilde{a}_{ij}:\) relative importance between criteria i and j
\(\tilde{Z}_{i}:\) fuzzy geometric average of criteria i
\(\tilde{\omega}_{i}:\) fuzzy weight corresponding to criteria i

Step 6: Hierarchy layer sequencing
In the final step, the sequential layers are linked together to calculate the fuzzy weight values for each alternative.

\[
\hat{U}_{i} = \sum_{j=1}^{n} \tilde{\omega}_{j} \cdot \tilde{r}_{ij}
\]

\(\hat{U}_{i}:\) fuzzy weight values of alternative i
\(\tilde{\omega}_{j}:\) fuzzy weight value for the decision key criteria
\(\tilde{r}_{ij}:\) performance score for the selected alternative \(X_{i}\) to the decision key criteria \(X_{j}\)

Step 7: Fuzzy ordering
Using the fuzzy number in Step 6, the best alternative was selected by ranking these fuzzy weight values.

4. EXAMPLE ILLUSTRATION
An empirical case of college T in Taiwan was conducted to prove the practicality of our proposed framework. College T is located in Hsinchu-county, over 300 faculties and 120 office staffs are employed by this college. The four schools including twelve departments and one institute contain more than 9,000 students.

Since ERP system is widely applying in industries, manpower demand of ERP projects implementation and ERP software operation is continuously growing in job market. Therefore, the ERP related courses are more important in the information management department of college T. In order to enhance student’s practical skill, the information management department decided to construct an ERP lab to exercise ERP courses. Thus, students could acquire exercising experience of ERP software beyond theoretical knowledge.

There were five department members formed the project team. The chairman of department is the project leader who organized four colleagues, all five members are familiar with ERP systems. After the project team was confirmed, the three-phase framework procedure was going on.

4.1 Identification Phase
Firstly, characteristics identification of our case is an ERP system selection problem, thus, the ultimate goal of 0th layer is represented. Next, from the viewpoint of project management, there are four decision criteria belongs to 1st layer: performance (including fundamental and distinctive performance), cost and time. The fundamental performance (software quality) criteria which are captured from McCall model are spread on 2nd and 3rd layers. The distinctive performance criteria may be different in diverse ERP projects. We adopt interview to elicit user’s requirements owing to it is an efficiency rule
According to the particular characteristics of this ERP project, the purpose of this ERP lab is course teaching. Five distinctive performance criteria of ERP system are defined by project members and put on 2nd layer:

1. The market share of ERP system in Taiwan;
2. Manpower demand quantity of job market;
3. Certification system of ERP software;
4. Cooperative inclination of ERP vendor;
5. Seed teacher’s training of ERP vendor.

The remaining two decision criteria of 1st layer are cost and time of project implementation, respectively. Further, the cost criteria is deployed into two sub criteria in 2nd layer. One is ERP software and relevant software cost, another is collocated hardware cost. Finally, total 19 criteria are fully extracted.

4.2 Searching Phase

Unqualified alternatives are eliminated by three constraints: performance, cost and time. In performance element, alternative ERP vendors intensively demonstrate each of their software and the project members test each software functions, respectively. The project team members also interview every ERP vendors and many ERP industrial users to understand the performance criteria of ERP software. Besides, the project team also takes counsel with Chinese Enterprise Resource Planning Soci-
enty (CERPS) about ERP software in Taiwan. Next, the cost and time factors are subjected to total budget and implementation schedule of the project.

After two weeks investigate process, the project team eliminates unqualified ERP vendors, and three ERP systems sift out and become the candidate alternatives. Among the three candidates, vender S is an Europe ERP system and vender D, F are two local ERP systems in Taiwan. We assume 19 criteria and three alternatives are independence in this problem so that to process the FAHP calculating. A complete hierarchy structure is shown in Fig. 4.

4.3 Analyzing Phase

Following the stepwise FAHP method as mentioned above, the fuzzy weights of 1st layer is calculated by five decision makers as shown in Table 1. After the fuzzy weights of layer 2nd and 3rd has been computed through the same step and link three layers together, the final fuzzy weights of entire 19 criteria is presented in Table 2. Table 3 lists the fuzzy scores for three alternatives relative to the first criteria, other fuzzy scores relative to remaining 18 criteria are computing as the same way. The final evaluation is presented as Table 4.

As shown in Table 4, a ranking rule which shows below is using to support the project team making the final decision. Hence, the project team agrees that vender D is the most suitable alternative for the information management department of college T.

### Table 1. Fuzzy weights of 1st layer

<table>
<thead>
<tr>
<th>Criteria of 1st layer</th>
<th>Weight</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamental performance (Software quality)</td>
<td>(0.097, 0.156, 0.284)</td>
<td>4</td>
</tr>
<tr>
<td>Distinctive performance</td>
<td>(0.187, 0.233, 0.321)</td>
<td>2</td>
</tr>
<tr>
<td>Cost</td>
<td>(0.339, 0.412, 0.614)</td>
<td>1</td>
</tr>
<tr>
<td>Implementation time</td>
<td>(0.164, 0.199, 0.258)</td>
<td>3</td>
</tr>
</tbody>
</table>

### Table 2. Final fuzzy weights of entire 19 criteria

<table>
<thead>
<tr>
<th>Criteria hierarchy</th>
<th>Weight</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamental performance (Software quality)</td>
<td>Correctness</td>
<td>(0.018, 0.033, 0.106)</td>
</tr>
<tr>
<td></td>
<td>Reliability</td>
<td>(0.006, 0.016, 0.050)</td>
</tr>
<tr>
<td></td>
<td>Usability</td>
<td>(0.002, 0.008, 0.028)</td>
</tr>
<tr>
<td></td>
<td>Integrity</td>
<td>(0.001, 0.003, 0.016)</td>
</tr>
<tr>
<td></td>
<td>Efficiency</td>
<td>(0.003, 0.007, 0.029)</td>
</tr>
<tr>
<td></td>
<td>Product revision</td>
<td>Maintainability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flexibility</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Testability</td>
</tr>
<tr>
<td></td>
<td>Product transition</td>
<td>Portability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reusability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Interoperability</td>
</tr>
<tr>
<td>Distinctive performance</td>
<td>Market share</td>
<td>(0.026, 0.043, 0.054)</td>
</tr>
<tr>
<td></td>
<td>Manpower demand</td>
<td>(0.005, 0.018, 0.037)</td>
</tr>
<tr>
<td></td>
<td>Certification system</td>
<td>(0.018, 0.029, 0.038)</td>
</tr>
<tr>
<td></td>
<td>Cooperative inclination</td>
<td>(0.041, 0.076, 0.124)</td>
</tr>
<tr>
<td></td>
<td>Teacher’s training</td>
<td>(0.034, 0.067, 0.097)</td>
</tr>
<tr>
<td>Cost</td>
<td>Software cost</td>
<td>(0.247, 0.295, 0.384)</td>
</tr>
<tr>
<td></td>
<td>Hardware cost</td>
<td>(0.084, 0.117, 0.189)</td>
</tr>
<tr>
<td>Implementation time</td>
<td></td>
<td>(0.164, 0.199, 0.258)</td>
</tr>
</tbody>
</table>

### Table 3. Fuzzy scores for three alternatives relative to the “Correctness” criteria

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Score relative to Correctness</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vender S</td>
<td>(0.450, 0.568, 0.789)</td>
<td>7</td>
</tr>
<tr>
<td>Vender D</td>
<td>(0.251, 0.364, 0.432)</td>
<td>2</td>
</tr>
<tr>
<td>Vender F</td>
<td>(0.025, 0.068, 0.230)</td>
<td>3</td>
</tr>
</tbody>
</table>

### Table 4. Final evaluation of FAHP analysis

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Final evaluation</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vender S</td>
<td>(0.11394, 0.26285, 0.61203)</td>
<td>3</td>
</tr>
<tr>
<td>Vender D</td>
<td>(0.18548, 0.35513, 0.76069)</td>
<td>1</td>
</tr>
<tr>
<td>Vender F</td>
<td>(0.16506, 0.33389, 0.68885)</td>
<td>2</td>
</tr>
</tbody>
</table>
Rule 1: The larger the Mode is, the larger is the fuzzy number.
Rule 2: The larger the Right Spread is, the larger is the fuzzy number.

5. CONCLUSION

This study proposes a three-phase systematic MCDM framework to select an appropriate ERP system. This framework combines ERP software quality factors and FAHP which offers decision makers a more comprehensive viewpoint and also proffers decision makers an effectiveness and efficiency procedure.

The proposed framework contributes two major advantages:

(a) Combining the McCall software quality model to interpret the performance term of project management, a more complete and flexible overall framework is conducted for ERP selection problem.

(b) Adopting FAHP method is more practical to solve the real-world MCDM problems.

A successful case is applied to prove our proposed model is practical for use. Among the case, there are 19 criteria sifted out. We found that cost issue is the most important factor for college T and implementation time is the second important factor. Among the distinctive performance factors, cooperative inclination, teacher’s training and market share are the top three important criteria. Between the software quality factors, correctness is the most important criteria. Besides, owing to the purpose of this ERP project is for course teaching, the integrity with other information systems and the efficiency of ERP software are the unimportant criteria in this case.

REFERENCES


