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Designing a MCDM Model for Selection of an Optimal ERP Software in Organization

Nguyen Van Thanh

Faculty of Commerce, Van Lang University, Ho Chi Minh City 70000, Vietnam; thanh.nguyenvan@vlu.edu.vn

Abstract: Among the growth of the Industrial Revolution 4.0 and moving towards 5.0, the application of science and technology is a decisive factor in catching up with new business trends. In particular, the application of the enterprise resources planning (ERP) towards enterprise management is extremely important. ERP systems help businesses save time and effort in managing projects and utilizing resources. Instead of manual handling, the processes are carried out automatically. At the same time, the system operates correctly and efficiently which avoids errors. In this work, the author explored the application of a fuzzy multicriteria decision making (FMCDM) method including Fuzzy Analytic Hierarchy Process model (FAHP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) model for the evaluation of various ERP software (mainly warehouse and inventory management module). First, the fuzzy AHP model is applied to calculate the weights of criteria, and then, the obtained weights are used in the TOPSIS method for ranking of the alternatives. This study would assist decision makers in an ERP implementation environment in deciding a suitable ERP software for various industries.

Keywords: enterprise resources planning (ERP); decision making; fuzzy theory; MCDM Model

1. Introduction

The process of global integration brings many opportunities along with challenges. To improve operational efficiency, most of the leading corporations apply enterprise resource planning (ERP) systems to manage their business activities and consider this a key factor in the success of their business. Deloitte Consulting [1] define an ERP system as a packaged business solution that is designed to automate and integrate business processes, share common data and practices across the enterprise, and provide access to information in a real time environment. Vietnamese enterprises have been approaching and applying ERP systems in their business operations to improve business efficiency and competitiveness in domestic and international markets. The overarching goal of ERP systems is to ensure appropriate business resources such as human, material, machinery, and financial resources are available in sufficient quantities when needed by using planning and scheduling tools.

Many companies implemented an ERP system to address a number of immediate problems such as poor systems. ERP systems bring many benefits to businesses such as [2]:

✓ Improved management decision making.
✓ Improved financial management.
✓ Ease of expansion/growth and increased flexibility.
✓ Improved customer service and retention.
✓ Faster, more accurate transactions.
✓ Improved inventory/asset management.
✓ Headcount reduction.
✓ Fewer physical resources/better logistics and Increased revenue.

Businesses always want to catch the trend of digital transformation, help growth, and create a different competitive position when applying technology. However, the decision to invest in an applied technology solution for businesses is not easy. Multi-criteria decision
making (MCDM) is a field of study focused on the analysis of various available alternatives in a situation including everyday life, social sciences, engineering, art, medicine, and many other fields such as supplier evaluation and selection [3], location selection [4], renewable energy sectors [5], medical [6], and vendor selection [7]. MCDM is one of the most popular decision-making models used in different fields.

MCDM is a branch of operational research that is generally used to evaluate complex situations that involved multiple and conflicting objectives in a set of predetermined alternatives. Despite a popular problem in today’s applications, there are still very few studies that considers fuzzy logic combined with MCDM Models that assist in the decision-making process for the implementation of ERP systems for businesses especially since popular qualitative data collection methods only provide unclear opinions from the data source. This is a reason why the author proposed a fuzzy MCDM Model including Fuzzy Analytic Hierarchy Process model (FAHP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) model for the evaluation of various ERP software in this study. The primary goal of this work is to propose a fuzzy MCDM Model for ERP software evaluation and selection in the garment industry. First, the AHP model combined with fuzzy theory is used for calculating the weight of evaluating criteria, and the TOPSIS model is utilized for ranking various ERP systems alternatives.

The rest of this paper is structured as follows. Section 2 describes relevant literature about the applications of MCDM Models in many fields of science. Section 3 presented the basic theory of two MCDM Models. In Section 4, the proposed model is utilized in a real-world ERP supplier evaluation case study to demonstrate its feasibility. Section 5 concludes the research.

2. Literature Review

The multi-criteria decision-making model has been applied to support decision-making in many different fields [8–13]. Gürbüz et al. [14] used the MCDM Model for the evaluation of various ERP alternatives. In this work, the authors utilized three models including Measuring Attractiveness with a Categorical Based Evaluation Technique (MACBETH), Analytic Network Process (ANP), and Choquet integral (CI). Park et al. [15] combined the Quality of Service (QoS) with MCDM Model for SaaS ERP applications with Social Network. The result of this study presents a useful guideline for finding the most suitable SaaS ERPs system according to their correlation with the criteria.

Hinduja and Pandey [16] presented the hybrid fuzzy MCDM Model including DEMATEL, IF-ANP, and IF-AHP models to select a cloud-based ERP system for small and mid-size enterprises. Results show that the proposed fuzzy MCDM Model effectively handles the ERP selection problem. Kazancoglu and Burmaoglu [17] employed the TODIM method for the ERP software selection process of a steel forming and hot dip-galvanizing company. The proposed ERP selection model can apply to various industries including manufacturing companies.

Brzozowski and Birfer [18] applied the MCDM methods in the process of selecting appropriate ERP system by organizations. Temur and Bolat [19] showed that the ERP system selection problem area has high sensitivity to the uncertain environment, and decision makers should not undervalue the unsteadiness of criteria during the ERP system selection process, especially within volatile economies. Jafarnejad et al. [20] proposed a MCDM Model including the DEMATEL technique and fuzzy AHP technique for solving the ERP system selection problem with application to the steel industry. In this study, the most important criteria in ERP selection were identified using the Shannon entropy technique. Naveed et al. [21] proposed the group decision-making (GDM) based AHP model for evaluating and ranking critical success factors of the cloud ERP system. In this work, they consider five alternatives and 20 sub-criteria factors in the decision-making process. Amirkabiri and Rostamiyan [22] developed the MCDM Model for ERP system evaluation and selection. The authors use the AHP model to obtain importance and relative weighted criteria. Then, the weighted criteria are used as inputs for ranking priorities by
similarity with ideal solution to rank decision alternatives. Rouyendegh and Erkan [23] presented a comprehensive MCDM Model for selecting a suitable ERP system by using the AHP model.

Ayag and Yucekeya [24] used the MCDM Model including fuzzy analytic network process (ANP) based grey relational analysis (GRA) approach to evaluate the ERP system. In this work, the authors used the fuzzy extension of the ANP method to reflect the uncertainty and ambiguity of decision maker(s) facing problems in order to reach more reliable solution. Mohd. Raihan Uddi et al. [25] utilized the AHP-TOPSIS integrated model based on multi-criteria investigation to select the best ERP systems.

From this literature review, it is concluded that MCDM is the optimal technique for applications in complex situations that include multiple criteria and conflicting goals. This tool has received attention in all industries because of its flexibility for decision-makers in multiple problems. While there have been some studies about the application of MCDM techniques in solving the ERP software selection problem, few have considered the use of the MCDM Model, especially under fuzzy decision-making environments. Thus, in this study, we propose a fuzzy MCDM Model for optimal ERP software selection. ERP systems assist in controlling inventories across multiple warehouses in real-time by retrieving all information from all the items distributed among the supply chain networks. The application would help the company keep track on how the prices of their products change along the supply chain which would let them adjust their manufacturing or operating costs. Warehouse management systems (WMS) are another ERP-integrated tool that assists in the management of warehouses. The tool allows the warehouse to track all inventories currently operating inside the warehouse and could assist in handling as well, in order to optimize order management and shipment tracking. Nowadays, items that are moved to the end consumer are always tagged with traceable tools that assist logistics in tracking where products will be. Some of the technologies include bar-code and RFID. These technologies also assist in the inventory management inside the warehouse.

3. Methodology

The overall methodology of this study which investigates deciding an optimal ERP supplier includes the following steps:

1. Identification of the Problem.
   A set of criteria which are essential for an ERP implementation is first chosen by experts reading through key literature.

2. Application of FAHP.
   This stage involves each of the criteria identified in step 1 being weighed and ranked accordingly.

3. Application of TOPSIS.
   The final step is to apply TOPSIS to determine the ranking amongst the candidate systems which would help decision-makers choose a suitable candidate.

3.1. Fuzzy Set Theory

A Triangular Fuzzy Number (TFN) denoted as \( \tilde{L} \) consists of three subset values \( (l_1/l_2/l_3) \) [26]. The membership function is between [0, 1]. A triangular fuzzy number is shown in Figure 1.

\[
\mu(x|\tilde{L}) = \begin{cases} 
0, & x < l_1 \\
\frac{x-l_1}{l_2-l_1}, & l_1 \leq x \leq l_2 \\
\frac{l_3-x}{l_3-l_2}, & l_2 \leq x \leq l_3 \\
0, & x > l_3 
\end{cases}
\] (1)
A fuzzy number can be defined by its corresponding left and right-side representation:

\[
\tilde{L} = L^L(y), L^R(y)) = (l_1 - (l_2 - l_1)y, l_2, l_3 + (l_2 - l_3)y)
\]

with \( y \in [0,1] \)

3.2. Fuzzy Analytical Hierarchy Process (FAHP) Model

FAHP is an extension of the AHP model. Denote \( X = \{x_1, x_2, \ldots, x_n\} \) being the set of numeric values and \( T = \{t_1, t_2, \ldots, t_n\} \) being the finalized target set. The values are then denoted as [27]:

\[
L_i^1, L_i^2, \ldots, L_i^m, \quad i = 1, 2, \ldots, n
\]

where \( L_i^j(j = 1, 2, \ldots, m) \) are the triangular fuzzy numbers.

The fuzzy synthetic extent value of the \( i^{th} \) object is defined as:

\[
S_i = \sum_{j=1}^{m} L_i^j \otimes \left[ \sum_{j=1}^{m} L_i^j \right]^{-1}
\]

The possibility that \( L_1 \geq L_2 \) is defined as:

\[
V(L_1 \geq L_2) = \sup_{y \geq 1} \left[ \min\left( \mu_{L_1}(x), \mu_{L_2}(y) \right) \right]
\]

We have \( V(L_1 \geq L_2) = 1 \) if the pair \((x, y)\) exists with \( x \geq y \) and \( \mu_{L_1}(x) = \mu_{L_2}(y) \).

Due to the fact that \( L_1 \) and \( L_2 \) are convex fuzzy numbers, we have:

\[
V(L_1 \geq L_2) = 1, \text{ if } l_1 \geq l_2
\]

and

\[
V(L_2 \geq L_1) = \text{hgt}(L_1 \cap L_2) = \mu_{L_1}(d)
\]

The ordinate of the highest intersection point D between \( \mu_{L_1} \) and \( \mu_{L_2} \) is denoted by \( d \). With \( L_1 = (p_1, q_1, r_1) \) and \( L_2 = (p_2, q_2, r_2) \), the ordinate of point D is calculated by (8):

\[
V(L_2 \geq L_1) = \text{hgt}(L_1 \cap L_2) = \frac{l_1 - r_2}{(q_2 - r_2) - (q_1 - p_1)}
\]

In order to carry out an \( L_1 \) and \( L_2 \) comparison, we need to determine the values of \( V(L_1 \geq L_2) \) and \( V(L_2 \geq L_1) \).
The possibility of a convex fuzzy number being greater than \( k \) convex fuzzy numbers \( L_i (i = 1, 2, \ldots, k) \) is calculated as:

\[
V(L \geq L_1, L_2, \ldots, L_k) = V(L \geq L_1) \text{ and } (L \geq L_2)
\]

and \( (L \geq L_k) = \min V (L \geq L_i) \)

Under the assumption that:

\[
d'(B_i) = \min V(S_i \geq S_i)
\]

for \( t = 1, 2, \ldots, n \) and \( t\#i \), the weight vector is defined as:

\[
W' = (d'(B_1), d'(B_2), \ldots, d'(B_n))
\]

The normalized weight metric is calculated as follows:

\[
W = (d(B_1), d(B_2), \ldots, d(B_n))
\]

The consistency of the pairwise comparison matrices is tested using a classical consistency test utilized in all AHP processes where:

\[
CR = \frac{CI}{RI} = \frac{\lambda - n}{(n - 1) \times RI} \leq 0.1
\]

3.3. The Order of Preference by Similarity to the Ideal Solution Model Technique (TOPSIS)

There are seven steps associated with the implementation of TOPSIS as follows [28–30]:

**Step 1:** Develop an evaluation matrix with \( m \) alternatives and \( n \) criteria, with the intersection of each option and criteria denoted by \( x_{ij} \), yielding a matrix \( (x_{ij})_{m \times n} \).

**Step 2:** The matrix will undergo normalization \( (x_{ij})_{m \times n} \) to generate the matrix \( R = (x_{ij})_{m \times n} \) using the normalization method defined in Equation (13):

\[
r_{ij} = \frac{x_{ij}}{\sum_{k=1}^{m} x_{kj}}
\]

**Step 3:** Make the following weighted normalized choice matrix:

\[
t_{ij} = r_{ij} \cdot w_j, \ i = 1, 2, \ldots, m; \ j = 1, 2, \ldots, n
\]

where \( w_j = \frac{W_j}{\sum_{i=1}^{n} W_i} \), \( j = 1, 2, \ldots, n \) so that \( \sum_{j=1}^{n} w_j = 1 \), and \( W_j \) initial weight assigned to the indicator \( v_j, \ j = 1, 2, \ldots, n \).

**Step 4:** Identify the worst alternative \( (A_w) \) and the best alternative \( (A_b) \):

\[
A_w = \{ \langle \max(t_{ij}) | i = 1, 2, \ldots, m | j \in J_– \rangle, \langle \min(t_{ij}) | i = 1, 2, \ldots, m | j \in J_+ \rangle \} = \{ t_{wj} | j = 1, 2, \ldots, n \}
\]

\[
A_b = \{ \langle \min(t_{ij}) | i = 1, 2, \ldots, m | j \in J_– \rangle, \langle \max(t_{ij}) | i = 1, 2, \ldots, m | j \in J_+ \rangle \} = \{ t_{wj} | j = 1, 2, \ldots, n \}
\]

**Step 5:** Determine the \( L^2 \)–distance between the desired alternative \( i \) and the worst-case scenario \( A_w \):

\[
d_{iw} = \sqrt{\sum_{j=1}^{n} (t_{ij} - t_{wj})^2}, \ i = 1, 2, \ldots, m
\]
In addition, the distance between the goal alternative \( i \) and the worst case \( A_b \):

\[
d_b = \sqrt{\sum_{j=1}^{m} (t_{ij} - t_{bj})^2}, \quad i = 1, 2, \ldots, m
\]  

(18)

**Step 6:** Determine the degree of resemblance to the worst-case scenario:

\[
s_{iw} = \frac{d_{ib}}{(d_{iw} + d_{ib})}, \quad i = 1, 2, \ldots, m
\]  

(19)

\( s_{iw} = 1 \) if and only if the options’ solution is in the best possible scenario; and \( s_{iw} = 0 \) if and only if the options’ solution is in the worst possible scenario.

**Step 7:** Rank the options using \( s_{iw} (i = 1, 2, \ldots, m) \).

### 4. Results

ERP is gradually showing itself as a useful and indispensable tool to improve the efficiency of resource management, orient the general development, and create sustainable development for garment manufacturing enterprises. Currently, there are many different ERP system solutions, and decision-makers do not know which one is most appropriate for their business. The problems businesses often face when choosing an ERP system are unclear project goals, system features do not meet requirements, costs exceed budget, and deployment schedule does not go as planned, even halting the business activities of enterprises. ERP is an essential tool applied in the logistics and supply chain management field that handles wholesale or retail transactions. The tool can automate a number of different tasks that assist in many departments of a business such as accounting, human resources, or customer relationship (CRM). The application of ERP can also improve the inventory and overall supply chain management of the company. The authors of the research have applied MCDM tools in order to rank a number of ERP systems used in warehouse and inventory management.

In this work, the author explored the application of a fuzzy multicriteria decision making (FMCDM) method for the evaluation of various ERP software alternatives in a garment company. All criteria affecting decision processing are determined by experts and literature review (Table 1).

**Table 1.** List of criteria.

<table>
<thead>
<tr>
<th>No</th>
<th>Main Criteria</th>
<th>Sub-Criteria</th>
<th>Criteria Definition</th>
<th>Literature Review</th>
<th>Expert Opinions</th>
<th>Symbol of the Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Software related criteria</td>
<td>Compatibility</td>
<td>The suitability of the software compared to previous systems or the processes inside the business; whether the new software is comfortable for all users in the company.</td>
<td>Gürbüz et al. [14]</td>
<td>X</td>
<td>ERP01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Technical aspects</td>
<td>The technology implementations applied to the system including the system requirements, assets requirement, and hardware requirements.</td>
<td>Kazancoglu et al. [17]</td>
<td>X</td>
<td>ERP02</td>
</tr>
<tr>
<td>No</td>
<td>Main Criteria</td>
<td>Sub-Criteria</td>
<td>Criteria Definition</td>
<td>Literature Review</td>
<td>Expert Opinions</td>
<td>Symbol of the Criteria</td>
</tr>
<tr>
<td>----</td>
<td>------------------------</td>
<td>--------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------</td>
<td>-----------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Cost</td>
<td></td>
<td>The amount of investment required for businesses to implement the software within the business model. Lower cost is generally considered.</td>
<td>Gürbüz et al. [14] Temur et al. [19] Kazancoglu et al. [17]</td>
<td>X</td>
<td>ERP03</td>
</tr>
<tr>
<td>2</td>
<td>Implementation time</td>
<td></td>
<td>The time required for the software to be applied directly into the system.</td>
<td>Kazancoglu et al. [17]</td>
<td>X</td>
<td>ERP04</td>
</tr>
<tr>
<td></td>
<td>Functionality</td>
<td></td>
<td>The different functions that each ERP system provides that allows businesses to utilize to the best potential. Some functions are implemented but sometimes are not applied completely.</td>
<td>Temur et al. [19] Kazancoglu et al. [17]</td>
<td>X</td>
<td>ERP05</td>
</tr>
<tr>
<td></td>
<td>System reliability</td>
<td></td>
<td>How reliable the system is depending on the durability and accessibility over time. The system is also checked for its maintenance assessment and how frequent maintenance is required.</td>
<td>Gürbüz et al. [14] Temur et al. [19]</td>
<td>X</td>
<td>ERP06</td>
</tr>
<tr>
<td></td>
<td>Ease of customization</td>
<td></td>
<td>How accessible can the system be to change it according to the requirement of the vendor.</td>
<td>Kazancoglu et al. [17]</td>
<td>X</td>
<td>ERP07</td>
</tr>
<tr>
<td>2</td>
<td>Better fit with</td>
<td></td>
<td>Does the ERP assist in providing a clearer structure indicating how the business’s organization should be formed with a proper hierarchical system?</td>
<td>Gürbüz et al. [14]</td>
<td>X</td>
<td>ERP08</td>
</tr>
<tr>
<td></td>
<td>organizational structure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fit with parent/allied</td>
<td></td>
<td>The system can adapt to change and can assist with tasks with other ERP systems from the vendor.</td>
<td>Gürbüz et al. [14] Temur et al. [19]</td>
<td>X</td>
<td>ERP09</td>
</tr>
<tr>
<td></td>
<td>organizational system</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cross module integration</td>
<td></td>
<td>The system can easily be integrated with multiple modules from other ERP systems</td>
<td>Temur et al. [19]</td>
<td>X</td>
<td>ERP10</td>
</tr>
</tbody>
</table>
### Table 1. Cont.

<table>
<thead>
<tr>
<th>No</th>
<th>Main Criteria</th>
<th>Sub-Criteria</th>
<th>Criteria Definition</th>
<th>Literature Review</th>
<th>Expert Opinions</th>
<th>Symbol of the Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Support and service</td>
<td>How accessible is it for vendors to ask for support and require service from the providing company</td>
<td>Temur et al. [19]</td>
<td>X</td>
<td>ERP11</td>
</tr>
<tr>
<td>3</td>
<td>Customer related criteria</td>
<td>Methodology of software</td>
<td>How accessible is the ERP system to other users in the system</td>
<td>Gürbüz et al. [14]</td>
<td>X</td>
<td>ERP12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Domain knowledge</td>
<td>Where is the main domain located, and is it suitable for the company’s needs?</td>
<td>Gürbüz et al. [14]</td>
<td>X</td>
<td>ERP13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Market position</td>
<td>How strong is the ERP system in the market compared to other ERP systems?</td>
<td>Temur et al. [19] Kazancoglu et al. [17]</td>
<td>X</td>
<td>ERP14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reputation</td>
<td>How reputable is the ERP system compared to other ERP systems?</td>
<td>Gürbüz et al. [14]</td>
<td>X</td>
<td>ERP15</td>
</tr>
</tbody>
</table>

In the first stage of this work, the fuzzy AHP model is applied to calculate the weights of criteria; a result of FAHP model is shown in Table 2.

### Table 2. The weight of 15 sub criteria.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Fuzzy Sum of Each Row</th>
<th>Fuzzy Synthetic Extent</th>
<th>Degree of Possibility (Mi)</th>
<th>Normalization</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERP01</td>
<td>(10.44, 14.38, 19.93)</td>
<td>(0.03, 0.06, 0.11)</td>
<td>0.4536</td>
<td>0.0479</td>
</tr>
<tr>
<td>ERP02</td>
<td>(11.93, 16.13, 21.78)</td>
<td>(0.03, 0.06, 0.12)</td>
<td>0.5132</td>
<td>0.0542</td>
</tr>
<tr>
<td>ERP03</td>
<td>(14.07, 20.59, 28.18)</td>
<td>(0.04, 0.08, 0.15)</td>
<td>0.6731</td>
<td>0.0711</td>
</tr>
<tr>
<td>ERP04</td>
<td>(12.77, 18.39, 25.43)</td>
<td>(0.04, 0.07, 0.14)</td>
<td>0.6046</td>
<td>0.0639</td>
</tr>
<tr>
<td>ERP05</td>
<td>(18.85, 25.70, 32.92)</td>
<td>(0.05, 0.10, 0.18)</td>
<td>1.0000</td>
<td>0.1057</td>
</tr>
<tr>
<td>ERP06</td>
<td>(11.14, 15.40, 21.38)</td>
<td>(0.03, 0.06, 0.11)</td>
<td>0.4958</td>
<td>0.0524</td>
</tr>
<tr>
<td>ERP07</td>
<td>(10.61, 14.90, 20.88)</td>
<td>(0.03, 0.06, 0.11)</td>
<td>0.4797</td>
<td>0.0507</td>
</tr>
<tr>
<td>ERP08</td>
<td>(15.68, 22.71, 30.34)</td>
<td>(0.04, 0.09, 0.16)</td>
<td>0.9055</td>
<td>0.0957</td>
</tr>
<tr>
<td>ERP09</td>
<td>(16.49, 23.77, 32.08)</td>
<td>(0.05, 0.09, 0.17)</td>
<td>0.9416</td>
<td>0.0995</td>
</tr>
<tr>
<td>ERP10</td>
<td>(11.70, 16.89, 23.61)</td>
<td>(0.03, 0.06, 0.13)</td>
<td>0.6861</td>
<td>0.0725</td>
</tr>
<tr>
<td>ERP11</td>
<td>(8.94, 13.70, 18.80)</td>
<td>(0.03, 0.05, 0.10)</td>
<td>0.5108</td>
<td>0.0540</td>
</tr>
<tr>
<td>ERP12</td>
<td>(15.55, 20.10, 27.73)</td>
<td>(0.04, 0.08, 0.15)</td>
<td>0.8408</td>
<td>0.0888</td>
</tr>
<tr>
<td>ERP13</td>
<td>(9.39, 13.30, 19.17)</td>
<td>(0.03, 0.05, 0.10)</td>
<td>0.5127</td>
<td>0.0542</td>
</tr>
<tr>
<td>ERP14</td>
<td>(8.94, 12.35, 17.53)</td>
<td>(0.03, 0.05, 0.09)</td>
<td>0.4462</td>
<td>0.0471</td>
</tr>
<tr>
<td>ERP15</td>
<td>(8.81, 11.59, 16.58)</td>
<td>(0.02, 0.04, 0.09)</td>
<td>0.4005</td>
<td>0.0423</td>
</tr>
</tbody>
</table>

TOPSIS is a multi-criteria decision analysis method; TOPSIS is applied for ranking four ERP systems (ERPsys1, ERPsys2, ERPsys3, and ERPsys4). Normalized matrix and normalized weighted matrix are shown in Tables 3 and 4.
The authors have applied a two-method MCDM Model in order to rank various ERP software used in warehouse and inventory management. Previously, pure AHP models could not assist in clarifying verbal assessments of experts in the field. As fuzzy logic is applied into the AHP model, the criteria weighting is clearly shown and is ranked in a hierarchical system which solved the unclear opinions from experts and literature. Therefore, a combined Fuzzy-AHP (FAHP) is shown to solve this problem in the mathematical model. In order to rank the alternatives at the end, the author used the TOPSIS model in order to rank the four alternatives involved based on three main criteria (software related criteria, vendor related criteria, customer related criteria) and fifteen subcriteria (compatibility, technical aspects, cost, implementation time, functionality, system reliability, ease of customization, better fit with organizational structure, fit with parent/allied organizational system, cross-module integration, support and service, methodology of software, domain knowledge, market position, and reputation). The fundamental concept of the TOPSIS method is that the best alternative be by all means near to the positive ideal solution (PIS) and simultaneously the farthest negative ideal solution (NIS) [31]. As result from Table 5 and Figure 2, the ranking lists were ERPsys3, ERPsys1, ERPsys4, and ERPsys2, with...
scores of 0.5159, 0.5013, 0.4982, and 0.4760, respectively. Thus, alternative ERPsys3 is the optimal solution.

Table 5. Ci values of TOPSIS approach.

<table>
<thead>
<tr>
<th>ERP System Alternatives</th>
<th>Si⁺ Value</th>
<th>Si⁻ Value</th>
<th>Ci Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERPsys1</td>
<td>0.0451</td>
<td>0.0453</td>
<td>0.5013</td>
</tr>
<tr>
<td>ERPsys2</td>
<td>0.0560</td>
<td>0.0509</td>
<td>0.4760</td>
</tr>
<tr>
<td>ERPsys3</td>
<td>0.0635</td>
<td>0.0676</td>
<td>0.5159</td>
</tr>
<tr>
<td>ERPsys4</td>
<td>0.0606</td>
<td>0.0602</td>
<td>0.4982</td>
</tr>
</tbody>
</table>

5. Conclusions

Currently, the application of an ERP system in business operation and management is indispensable, but to be able to successfully deploy it, businesses need to consider choosing the most suitable ERP system for their business. Thus, ERP software selection is multicriteria decision making, and the decision maker must consider both qualitative and quantitative criteria. This work introduces a novel fuzzy MCDM Model based on fuzzy AHP and TOPSIS models to rank various ERP software (warehouse and inventory management model). Fuzzy theory combined with the AHP model is utilized to calculate the weight of criteria. TOPSIS is then employed to obtain values to rank the four ERP software. Based on experts’ opinions and the literature, a set of criteria for evaluating ERP software has been considered, including Software related criteria, vendor related criteria, and customer related criteria factors. The findings suggest that ERPsys3 is the most suitable.

The key takeaways of this study are listed below:

✓ The decision-making model is used to evaluate and decide on a suitable ERP software to be applied in any industry.

✓ This is the first study to apply the method that includes a real-life case study where the industry demanded a suitable ERP implementation but was unclear due to a high variability of ERP providers in the market.

✓ The study applied a suitable MCDM Model that could prove to be a suitable resource for decision-makers when choosing a suitable ERP system.

Future research can extend the application of the fuzzy number to develop new MCDM Models to support solving decision-making problems in other fields and industries. Studies can also be carried out to evaluate the performance of fuzzy MCDM Models in...
comparison with other extensions of MCDM Models such as TOPSIS, data envelopment analysis (DEA), the combined comprise solution (CoCoSo) method, etc.

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