Predicting the Success of B2B E-commerce in Small and Medium Enterprises: Based on Consistent Fuzzy Preference Relation

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Abstract: - This investigation establishes an analytical hierarchy framework to help SMEs predicting implementation success as well as identifying the actions necessary before implementing B2B e-commerce to increase e-commerce initiative feasibility. The consistent fuzzy preference relation is used to improve decision making consistency and effectiveness. A case study involving six influences solicited from a Taiwanese steel company is used to illustrate the feasibility and effectiveness of the proposed approach. The analytical results show that the three most influential factors are management support, industry characteristics and government policies; meanwhile, the three least influential factors are organizational culture, IT integration and firm size.

Key-Words: - B2B e-commerce; small and medium enterprises; multi-criteria decision making; consistent fuzzy preference relation

1. Introduction

The benefits of e-commerce are apparent not only for large firms but also for small and medium enterprises (SMEs) [8]. However, some governments have noted the relatively slow uptake of electronic commerce in the SME sector [2, 7]. Deciding whether to implement B2B is difficult in many organizations and particularly in SMEs. This vital decision may promote growth in an organization or lead to its downfall; consequently, all aspects of implementation must be considered before reaching a consensus within an organization.

Although cases of successful B2B e-commerce implementation have been widely reported, several noteworthy failures have also occurred worldwide. Implementing B2B e-commerce is time consuming, and the long-term impact on an organization may be unclear for some time. Since implementing B2B e-commerce in SMEs is a long-term commitment and is more limited in resources than large enterprises, the predicted value of successful implementation would be extremely useful when deciding whether to initiate B2B e-commerce. Therefore, the likelihood of successful implementation and an effective decision making process can facilitate implementation of B2B e-commerce in SMEs. Additionally, although previous studies of e-commerce adoption have examined user acceptance, consumer behavior, e-commerce software, investment decision making factors in adopting e-commerce, selection of e-commerce sites by the consumer, the impact of innovation and
pricing strategies [1, 3, 6, 10, 14, 15, 16, 17, 18, 21, 23, 24, 25], few studies have investigated the magnitude of all these factors on B2B e-commerce implementation in SMEs. Thus, elucidating the factors required for successful electronic commerce, particularly in the SME sector, is a worthwhile endeavor.

The focus on B2B e-commerce in SMEs has become an increasingly important topic for both researchers and SME managers. The proposed prediction model based on the reciprocal additive consistent fuzzy preference relation [9] in this study can help organizations identify key factors affecting B2B e-commerce implementation in SMEs and remedial action necessary to ensure successful implementation.

2. Reciprocal Additive Consistent Fuzzy Preference Relation

Many factors determine the success of B2B e-commerce implementation in SMEs. Essential considerations include not only financial issues but also organizational culture, government policies, industry characteristics and many others [5, 8, 11, 13, 19, 26, 27, 28]. In SMEs, B2B e-commerce systems must be implemented with care. Factors requiring consideration include the internal, external, qualitative and quantitative attributes of the enterprise. The numerous considerations suggest an analytical hierarchy is required to properly address the issue [12]. A well-known approach for effectively addressing this problem is the Analytic Hierarchy Process (AHP) proposed by Saaty [22]. The AHP methodology separates a complex decision issue into elemental problems to establish a hierarchical model. When the decision problem is hierarchically divided into smaller constituent parts, the relative importance of elements are compared pairwise at each level to establish a set of priorities. Although AHP is widely employed in diverse fields [4, 20], inconsistency increases as hierarchies of criteria or alternatives increase [30]. To address this dilemma, Herrera-Viedma et al. [9] presented a set of consistent fuzzy preference relations to facilitate the effectiveness and accuracy of decision-making. Each of these preference relations requires completion of all $\frac{n(n-1)}{2}$ judgments to produce a preference matrix containing $n$ elements. To reduce judgment time, this study employs the reciprocal additive consistent fuzzy preference relation proposed by Herrera-Viedmas et al. [9] as the basis for predicting the success of B2B e-commerce implementation in SMEs because it only requires $n-1$ judgments from a set of $n$ elements.

Herrera et al. proposed consistent fuzzy preference relations in accordance with two preference relations, namely multiplicative preference relation and fuzzy preference relation [29]. This study is based on the methodology of consistent fuzzy preference relations, which is presented below:

(1) Multiplicative preference relation. Experts express preferences regarding a set of alternatives since $X$ can be denoted by a preference relation matrix $A \subset X \times X$, $A = (a_{ij}), a_{ij} \in [0, 9]$, where $a_{ij}$ denotes the ratio of the preference degree of alternative $x_i$ over $x_j$. As $a_{ij} = 1$ indicates no difference between $x_i$ and $x_j$, $a_{ij} = 9$ indicates that $x_i$ is highly preferable to $x_j$. $A$ is assumed to be a multiplicative reciprocal, that is

$$a_{ij} \cdot a_{ji} = 1$$

(2) Fuzzy preference relation. Experts express preferences over a set of alternatives where $X$ is denoted by a positive preference relation matrix $P \subset X \times X$ with membership function: $\mu_p : X \times X \rightarrow [0, 1]$. 


where $p_i(x_i, x_j) = p_{ij}$ indicates the ratio of the preference intensity of alternative $x_i$ to that of $x_j$. Moreover, if $p_{ij} = \frac{1}{2}$ implies indifference between $x_i$ and $x_j$ ($x_i \sim x_j$), $p_{ij} = 1$ indicates that $x_i$ is absolutely preferred to $x_j$, $p_{ij} = 0$ indicates $x_j$ is absolutely preferred to $x_i$, and $p_{ij} > \frac{1}{2}$ indicates that $x_i$ is preferred to $x_j$ ($x_i > x_j$). Meanwhile, $P$ is assumed to be an additive reciprocal, given by

$$p_{ij} + p_{ji} = 1$$

(2)

Proposition 1 Reciprocal additive fuzzy preference relation

$$p_{ij} + p_{jk} + p_{ki} = \frac{1}{2} \quad \forall i, j, k$$

(3)

$$p_{ij} + p_{jk} + p_{ki} = \frac{3}{2} \quad \forall i < j < k$$

(4)

$$p_{i(k+1)} + p_{(i+1)k} + \cdots + p_{(j-1)j} + p_{ji} = \frac{j-i+1}{2} \quad \forall i < j$$

(5)

Proposition 2 Assuming a set of alternatives $X = \{x_1, x_2, \cdots, x_n\}$, which is associated with a multiplicative preference relation $A = (a_{ij}), a_{ij} \in [0, 9]$, then the corresponding reciprocal additive fuzzy preference relation $P = (p_{ij})$ with $p_{ij} \in [0, 1]$ to $A = (a_{ij})$ is defined as follows.

$$p_{ij} = g(a_{ij}) = \frac{1}{2}(1 + \log_9 a_{ij})$$

(6)

Using the transformation function $g(a_{ij})$, a multiplicative preference relation matrix can be transformed into various preference relations.

Notably, according to Proposition 1, only $n-1$ ($\{p_{12}, p_{23}, \cdots, p_{n-1n}\}$) judgements are required to construct consistent fuzzy preference relations. The other incomplete elements can be constructed by additive transitivity. If the preference matrix contains values that are not in the interval $[0, 1]$ but rather are in $[-a, 1+a]$, a linear transformation is required to preserve the reciprocity and additive transitivity, that is, $f:[-a, 1+a] \rightarrow [0, 1]$. For further detail see Herrera et al.[9].

3. Framework for Accurately Predicting the Success of B2B E-commerce Implementation in SMEs

3.1 Influential factors and framework of the prediction model

Figure 1 shows the hierarchical structure for addressing the problem of forecasting the success of B2B e-commerce implementation in SMEs. The influential factors are synthesized from the reviewed literature [5, 8, 11, 13, 19, 26, 27, 28] as well as consultations with and guidance from several experts, including two professors in information management, one professor in information engineering, three professors in business administration and three experienced B2B e-commerce project managers. The criteria and their attributes are summarized as follows: Management support ($C_1$), Firm size ($C_2$), IT integration ($C_3$), Organizational culture ($C_4$), Government policies ($C_5$) and Industry characteristics ($C_6$).

![Fig. 1. The analytical framework](image)

3.2 Hierarchical analytical process for predicting outcomes

3.2.1 Linguistic variables

Pairs of factors were compared using expressions, using a five level scale with values indicated by actual numbers (see Table 1).

Table 1. Linguistic terms for priority weights of influential factors
Additionally, three linguistic variables were used to measure the success of B2B e-commerce implementation in SMEs (see Table 2).

Table 2. Linguistic variables for probable outcomes of e-commerce implementation

<table>
<thead>
<tr>
<th>Definition</th>
<th>Intensity of importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equally important (EQ)</td>
<td>1</td>
</tr>
<tr>
<td>Weakly more important (WK)</td>
<td>3</td>
</tr>
<tr>
<td>Strongly more important (ST)</td>
<td>5</td>
</tr>
<tr>
<td>Very strongly more important (VS)</td>
<td>7</td>
</tr>
<tr>
<td>Absolutely more important (AB)</td>
<td>9</td>
</tr>
<tr>
<td>Intermediate values used to present compromise</td>
<td>2, 4, 6, 8</td>
</tr>
</tbody>
</table>

3.2.2 Prioritizing the influential factors

The procedures for the reciprocal additive consistent fuzzy preference relation for prioritizing influential factors are given below.

(1) Establish pairwise comparison matrices among all factors \((C_i, \ i = 1, 2, ..., n)\) in the dimensions of the hierarchy system. The evaluators \((E_k, \ k = 1, 2, ..., m)\) provide the more important of each pair of influential factors for a set of \(n - 1\) preference values \((a_{i1}, a_{i2}, ..., a_{i(n-1)}))\), for example:

\[
A^k = \begin{bmatrix}
C_1 & C_2 & \ldots & C_n \\
C_1 & 1 & a_{12}^k & x & x \\
C_2 & x & 1 & a_{23}^k & x \\
& \vdots & \vdots & \vdots & \vdots \\
C_n & x & x & \ldots & 1
\end{bmatrix}
\]

Where \(a_{ij}^k\) denotes the preference intensity toward influential factors \(i\) and \(j\) assessed by evaluator. The sign “x” indicates the remaining \(a_{ij}^k\), which can be derived via inverse comparison.

(2) Transform the preference value \(a_{ij}^k\) into \(p_{ij}^k\) using an interval scale \([0, 1]\), then derive the remaining \(p_{ij}^k\) based on the reciprocal transitivity property as follows

\[
p^k = \frac{1}{2}(1 + \log_a A^k)
\]

where \(p_{ij} = 0.5\) indicates no difference between factors \(i\) and \(j\). The remaining \(p_{ij}^k\) can be calculated using Eqs (2) and (5). However, in an interval \([-a, 1 + a]\), a transformation function is required to preserve the reciprocity and additive transitivity. The transformation function is

\[
f(p_{ij}^k) = \frac{(p_{ij}^k + a)}{(1 + 2a)}
\]

where \(a\) denotes the absolute value of the minimum negative value in this preference matrix.

(3) Pull the opinions of evaluators to obtain the aggregated weights of the factor. This study uses the average value to integrate the judgment values of \(m\) evaluators, namely

\[
p_{ij} = \left(\frac{1}{m} p_{ij}^1 + p_{ij}^2 + \ldots + p_{ij}^m\right)
\]

(4) The aggregated fuzzy preference relation matrices \(r_{ij}\) are normalized to indicate the normalized fuzzy preference values of each influential factor, such as
(9) Using the $w_i$ denoting the average priority weight of influential factor $i$, the priority of each factor can be obtained, that is

$$w_i = \frac{1}{n} \sum_{j=1}^{n} r_{ij}$$  \hspace{1cm} (10)

3.2.3 Obtaining the synthetic utility value with each factor

The evaluators were asked to express their subjective judgments regarding the preference ratings of probable outcomes of B2B e-commerce implantation for SMEs ($A_u$, $u=1,2,...,s$), $s=2$ (S: success, F: failure), with respect to each influential factor in linguistic terms.

For each influential factor, the evaluators were requested to evaluate the probabilities of two outcomes for a set of 1−s preference data $(g_{12}, g_{23}, ..., g_{(s-1)s})$, for example

$$
\begin{bmatrix}
A_1 & A_2 & \ldots & A_i \\
A_i & 1 & \frac{1}{g_{12}} & x & x \\
\vdots & \vdots & \vdots & \vdots & \vdots \\
A_i & x & x & \ldots & 1
\end{bmatrix}
$$

where $i g^k_{uv}$ represents the performance value assigned by evaluator $k$ to probable outcomes $u$ and $v$ based on influential factor $i$.

Next, the preference value $i g^k_{uv}$ is transformed within the range $[\frac{1}{5}, 5]$ into $i q^k_{uv}$ in an interval scale $[0, 1]$, and the remaining $i q^k_{uv}$ are obtained via the reciprocal transitivity property as follows

$$
\begin{bmatrix}
A_1 & A_2 & \ldots & A_i \\
A_i & 0.5 & i g_{12}^k & x & x \\
\vdots & \vdots & \vdots & \vdots & \vdots \\
A_i & x & 0.5 & i g_{23}^k & x \\
\vdots & \vdots & \vdots & \vdots & \vdots \\
A_i & x & x & \ldots & 0.5
\end{bmatrix}
$$

(3) The opinions of evaluators are then taken to obtain the transformed synthetic rating of the probable outcome for each influential factor $i q^k_{uv}$ which denotes the transformed fuzzy preference value of evaluator $k$ for assessing probable outcomes $u$ and $v$ in terms of influential factor $i$. This study using the notation of the average value, this study integrates the judgment values of $m$ evaluators; that is

$$i q^k_{uv} = \frac{1}{m} \sum_{j=1}^{m} i q^m_{uv}$$  \hspace{1cm} (11)

(4) After normalizing the synthetic fuzzy preference rating of the probable outcomes for each influential factor, $i q^k_{uv}$ is adopted to indicate the normalized rating of probable outcomes $u$ and $v$ with respect to influential factor $i$, for example

$$i q^k_{uv} = i q^k_{uv} / \sum_{u=1}^{s} i q^k_{uv}$$  \hspace{1cm} (12)

(5) Consequently, $- \eta_u$ denotes the average rating of probable outcome $u$ with respect to influential factor $i$. The desired rating of each probable outcome can be derived for each influential factor, that is,

$$- \eta_u = \frac{1}{s} \sum_{v=1}^{s} i q^k_{uv}$$  \hspace{1cm} (13)

3.2.4 Obtaining the priority weight for probable outcomes

A preferred value $R_u$ for the company is obtained by multiplying the priority weights of influential factors by the ratings of probable outcomes. That is,

$$R_u = \sum_{i=1}^{n} - \eta_u \ w_i$$  \hspace{1cm} (14)

4. Empirical Case for Proposed Model

This study examined a Taiwan steel company as an example to demonstrate the analytical framework. Twelve questionnaires were dispatched to survey...
candidates to analyze the probability of successful B2B e-commerce implementation.

4.1 Weighting calculation of influential factors

Six major factors were considered in predicting the success of B2B e-commerce implementation considered here. The following examples clarify the computational process used to derive the priority weights using the reciprocal additive consistent fuzzy preference relation approach.

(1) Based on interviews with twelve representatives regarding the importance of six influential factors, Table 3 lists the pairwise comparison matrices for a set of $n-1$ neighbouring criteria $\{a_{12}, a_{23}, a_{34}, a_{45}, a_{56}\}$.

Table 3. The linguistic terms toward six factors assessed by evaluators

<table>
<thead>
<tr>
<th>$E_1$</th>
<th>$E_2$</th>
<th>$E_3$</th>
<th>$E_4$</th>
<th>$E_5$</th>
<th>$E_6$</th>
<th>$E_7$</th>
<th>$E_8$</th>
<th>$E_9$</th>
<th>$E_{10}$</th>
<th>$E_{11}$</th>
<th>$E_{12}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_1$</td>
<td>WE</td>
<td>WE</td>
<td>VT</td>
<td>EQ</td>
<td>WE</td>
<td>ST</td>
<td>EQ</td>
<td>ST</td>
<td>VS</td>
<td>VS</td>
<td>VS</td>
</tr>
<tr>
<td>$C_2$</td>
<td>WE</td>
<td>ELW</td>
<td>LVLA</td>
<td>EQ</td>
<td>WE</td>
<td>LWS</td>
<td>LST</td>
<td>WE</td>
<td>EQ</td>
<td>LWS</td>
<td>LST</td>
</tr>
<tr>
<td>$C_3$</td>
<td>WK</td>
<td>ELW</td>
<td>LSLV</td>
<td>WE</td>
<td>WK</td>
<td>ELW</td>
<td>LST</td>
<td>WE</td>
<td>EQ</td>
<td>LWS</td>
<td>ST</td>
</tr>
<tr>
<td>$C_4$</td>
<td>LWLS</td>
<td>ELW</td>
<td>VT</td>
<td>ELW</td>
<td>LWLS</td>
<td>WE</td>
<td>ELW</td>
<td>ELW</td>
<td>LSLV</td>
<td>FW</td>
<td>FW</td>
</tr>
<tr>
<td>$C_5$</td>
<td>WE</td>
<td>WE</td>
<td>ST</td>
<td>ELW</td>
<td>WE</td>
<td>EQ</td>
<td>LST</td>
<td>ELW</td>
<td>WE</td>
<td>LWS</td>
<td>LVS</td>
</tr>
</tbody>
</table>

(2) Eqs. (6)-(10) was used to yield the result. Table 4 lists the priority weight and rank of each influential factor assessed by twelve evaluators. The ranks of the influential factors weights are thus substituted as:

$C_1(0.185) > C_4(0.174) > C_5(0.165) > C_3(0.164) > C_4(0.165) > C_2(0.128)$

Table 4. Normalized matrix of priority weight and rank of influential factors

<table>
<thead>
<tr>
<th>$C_1$</th>
<th>$C_2$</th>
<th>$C_3$</th>
<th>$C_4$</th>
<th>$C_5$</th>
<th>$C_6$</th>
<th>Total Avg</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_1$</td>
<td>0.187</td>
<td>0.182</td>
<td>0.152</td>
<td>0.185</td>
<td>0.186</td>
<td>0.187</td>
<td>1.079</td>
</tr>
<tr>
<td>$C_2$</td>
<td>0.124</td>
<td>0.136</td>
<td>0.106</td>
<td>0.129</td>
<td>0.127</td>
<td>0.124</td>
<td>0.745</td>
</tr>
</tbody>
</table>

4.2 Probable outcomes with respect to influential factors

The priority weights of two probable outcomes were calculated as follows.

(1) Examining the situation of this company, the twelve evaluators were interviewed to assess which is more likely to occur given each influential factor. Table 5 lists the opinions of these twelve evaluators regarding their preference intensities for probable outcomes resulting from each influential factor.

Table 5. The linguistic variables given to the priority weight of probable outcomes

<table>
<thead>
<tr>
<th>$E_1$</th>
<th>$E_2$</th>
<th>$E_3$</th>
<th>$E_4$</th>
<th>$E_5$</th>
<th>$E_6$</th>
<th>$E_7$</th>
<th>$E_8$</th>
<th>$E_9$</th>
<th>$E_{10}$</th>
<th>$E_{11}$</th>
<th>$E_{12}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_1$</td>
<td>S</td>
<td>H</td>
<td>F</td>
<td>H</td>
<td>F</td>
<td>H</td>
<td>F</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>$C_2$</td>
<td>S</td>
<td>L</td>
<td>H</td>
<td>VHG</td>
<td>LHF</td>
<td>H</td>
<td>HF</td>
<td>H</td>
<td>VH</td>
<td>H</td>
<td>F</td>
</tr>
<tr>
<td>$C_3$</td>
<td>S</td>
<td>L</td>
<td>FH</td>
<td>F</td>
<td>F</td>
<td>VH</td>
<td>H</td>
<td>LH</td>
<td>F</td>
<td>LH</td>
<td>F</td>
</tr>
<tr>
<td>$C_4$</td>
<td>S</td>
<td>LH</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>LHF</td>
<td>H</td>
<td>LF</td>
<td>F</td>
<td>LF</td>
<td>H</td>
</tr>
<tr>
<td>$C_5$</td>
<td>S</td>
<td>VH</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>F</td>
</tr>
<tr>
<td>$C_6$</td>
<td>S</td>
<td>H</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
</tbody>
</table>

(2) Using Eq. (11)-(13), the synthetic rating of probable outcomes can be obtained and Table 6 lists the normalized values and priority weights of all criteria.

Table 6. All criteria and preference rate of probable outcomes

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Priority weight</th>
<th>Weighted rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_1$</td>
<td>0.185</td>
<td>0.587</td>
</tr>
<tr>
<td>$C_2$</td>
<td>0.128</td>
<td>0.566</td>
</tr>
</tbody>
</table>

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4.3 Weighting the predication priorities
As Table 6 shows, Eq. (14) is used to determine the priority weights of six influential factors and the priority ratings of two probable outcomes in addition to the preference weightings of the candidates. From Table 6, the ranking of probable outcomes of e-commerce implementation is obtained as follows: Success $S$ (0.550) > Failure $F$ (0.450). Evaluators clearly believe that the probable outcome of B2B e-commerce implementation for SMEs is “success”.

5. Conclusions
Based on the opinions of all survey respondents, the following findings were obtained:

Analytical results indicate that management support, industry characteristics and government policies are more important than other factors. This analytical result also demonstrates that B2B e-commerce implementation in this company may break down. The company should be more concerned with seeking support from top managers, increasing firm size, improving IT integration and IT sophistication or changing the organizational culture to increase the likelihood of success in implementing B2B e-commerce.

The multi-criteria decisionmaking model for predicting the success of B2B e-commerce implementation presented here is clearly applicable to the evaluation process. The proposed approach is based on the reciprocal additive consistent fuzzy preference relation rather than conventional multiplicative preference relation. Namely, this method considers only $n-1$ judgments whereas the traditional analytic hierarchy approach (that is AHP or FAHP) uses $\frac{n(n-1)}{2}$ judgments in a preference matrix with $n$ attributes or alternatives. Application of the proposed approach is clearly faster and more efficient than the conventional analytic hierarchy methodologies. This advantage is a key contribution of this study. The findings of this study provide a reference for managers and decision makers considering implementation of B2B e-commerce in small and medium enterprises.

References


