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Research Paper

Knowledge Management System Selection and Evaluation for Small and Medium Enterprises Using Fuzzy Analytic Hierarchy Process Approach

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Abstract
Knowledge management system selection and evaluation plays an important role in improving the competitiveness of small and medium enterprises. The process of evaluating and selecting the knowledge management system requires multiple criteria and decision makers. This study applies fuzzy analytic hierarchy processapproach to evaluate and select the knowledge management systems. The criteria used in the model includeknowledge store, knowledge map, knowledge recommendation, knowledge search,and knowledge community. Simulation example is used to clarify the application steps of the proposed model.
Keywords: *Knowledge Management System; Small and Medium Enterprises; Fuzzy AHP*

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I. Introduction

Knowledge management is one of the important tasks in small and medium enterprises to maintain and strengthen their competitive advantage (Chopra et al., 2021). A knowledge management system refers to a system of computers, equipment, and technology used to store and manage an organization's knowledge. Selecting the suitable knowledge management system is important for better storing and using knowledge, as well as supporting the use of knowledge within and across organizations. There have been a number of studies that provide criteria for evaluating and selecting the knowledge management systems. Li et al. (2014) used the integrated quality function deployment (QFD) model with technique for order preference by similarity to an ideal solution (TOPSIS) to evaluate and select the knowledge management system. The criteriawhich were used in their study include: knowledge finding, knowledgestoring, knowledgesharing, personalizedsupporting, knowledge store, knowledge map, knowledge recommendation, knowledge search and knowledge community.Folkens and Spiliopoulou (2014) summarized the criteria to access the knowledge management system including: knowledge identification, knowledge acquisition, knowledge creation, knowledge distribution, knowledge utilization and knowledge preservation.Sanayei et al. (2009) developed amulti criteria decision making model based on the fuzzy VIKORapproach to help organizations in selectingsuitableknowledge portal system. In order to select the suitable knowledge management system, it is necessary to use many evaluation criteria, many decision makers with many alternatives. Therefore, the process of evaluating and selecting a knowledge management system can be viewed as a multi-criteria decision-making process.

Nowadays, the fuzzy AHP method is one of the commonly used multi-criteria decision-making methods to evaluate the alternative in vague information environment. In this study, the fuzzy AHP method proposed by Hue et al. (2022) is applied to evaluate and select the knowledge management system. The application steps of fuzzy AHP method include: (i) building a pairwise comparison matrix; (ii) determining the value of the fuzzy synthetic extent; (iii) calculating the weight vectors; (iv) ranking the alternatives.

II. Fuzzy numbers

There are various ways of defining fuzzy numbers. This paper defines the concept of fuzzy numbers as follows (Dubois & Prade, 1978).

Definition 1. A real fuzzy number A is described as any fuzzy subset of the real line *R* with membership function $A(x)$ that can be generally be defined as:

(a) f_A is a continuous mapping from *R* to the closed interval $[0, \omega]$.

(b) $f_A(x) = 0$, for all $x \in (-\infty, a]$;

(c) f_A is strictly increasing on $[a, b]$;

(d) $f_A(x) = \omega$, for all $x \in [b, c]$;

(e) f_A is strictly decreasing on $[c, d]$;

(f) $f_A(x) = 0$, for all $x \in (d, \infty]$,

where a, b, c and d are real numbers. Unless elsewhere specified, this research assumed that A is convex and bounded (i.e. $-\infty < a, d < \infty$).

Definition 2. The fuzzy number $A = (a, b, c, d; \varpi)$ isa trapezoidal fuzzy number if its membership function is given by:

$$f_A(x) = \begin{cases} \omega(x-a)/(b-a), & a \le x \le b, \\ \varpi, & b \le x \le c, \\ \omega(x-d)/(c-d), & c \le x \le d, \\ 0, & \text{otherwise}, \end{cases} \quad (1)$$

where $f_L^A(x)$ and $f_A^R(x)$ are the left and right membership functions of *A*, respectively. If $\varpi = 1$, then A is a normal fuzzy number; otherwise, it is said to be a non-normal fuzzy number. If $f_A^L(x)$ and $f_A^R(x)$ are both linear, then A is referred to as a trapezoidal fuzzy number and is usually denoted by $A = (a, b, c, d; \varpi)$ or simply $A = (a, b, c, d)$ if $\varpi = 1$. In particular, when $b = c$, the trapezoidal fuzzy number is reduced to a triangular fuzzy number, and can be denoted by $A = (a, b, d; \varpi)$ or $A = (a, b, d)$ if $\varpi = 1$. So, triangular fuzzy numbers are special cases of trapezoidal fuzzy numbers.

III. Hue's method on fuzzy AHP

This study applies the fuzzy AHP approach proposed by Hue et al. (2022). The steps of Hue et al.'s (2022) fuzzy AHP approach are as the following:

Step 1: Defining the generalized triangular fuzzy comparison matrix. The matrix is expressed by:

$$\tilde{T} = (\tilde{x}_{ij})_{nxn} = \begin{bmatrix} (1,1,1; w_{11}) & (o_{12}, p_{12}, q_{12}; w_{12}) & \cdots & (o_{1n}, p_{1n}, q_{1n}; w_{1n}) \\ (o_{21}, p_{21}, q_{21}; w_{21}) & (1,1,1; w_{22}) & \cdots & (o_{2n}, p_{2n}, q_{2n}; w_{2n}) \\ \vdots & \vdots & \vdots & \vdots \\ (o_{n1}, p_{n1}, q_{n1}; w_{n1}) & (o_{n2}, p_{n2}, q_{n2}; w_{n2}) & \cdots & (1,1,1; w_{nn}) \end{bmatrix}$$

where $\tilde{x}_{ij} = (o_{ij}, p_{ij}, q_{ij}; w_{ij})$, $\tilde{x}_{ij}^{-1} = (1/q_{ij}, 1/p_{ij}, 1/o_{ij}; w_{ij})$ for $i, j = 1, \ldots, n$ and $i \neq j$.

Step 2: Determining the values of the fuzzy synthetic extents.

The values of fuzzy synthetic extents, S_i were defined in the following equation:

$$S_i = \left(g_i, h_i, k_i; \min(w_{ij})\right) = \sum_{j=1}^{n} M_{g_i}^{j} \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{n} M_{g_i}^{j}\right]^{-1}$$

$$= \left(\frac{\sum_{j=1}^{n} o_{ij}}{\sum_{j=1}^{n} o_{ij} + \sum_{k=1,k\neq i}^{n} \sum_{j=1}^{n} q_{kj}}, \frac{\sum_{j=1}^{n} p_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n} p_{ij}}, \frac{\sum_{j=1}^{n} q_{ij}}{\sum_{j=1}^{n} q_{ij} + \sum_{k=1,k\neq i}^{n} \sum_{j=1}^{n} o_{kj}}; \min(w_{ij}) \right) \quad (2)$$

where $\sum_{j=1}^{n} M_{g_i}^{j} = \left(\sum_{j=1}^{n} o_{ij}, \sum_{j=1}^{n} p_{ij}, \sum_{j=1}^{n} q_{ij}; \min(w_{ij}) \right),\ i, j = 1, 2, ..., n$

Step 3: Calculating the centroid indices of the fuzzy synthetic extent, S_i by using Dat et al.'s (2012) approach. Suppose $S_1, S_2, ..., S_n$ are the values of the fuzzy synthetic extents. The centroid point of all fuzzy numbers $S_i = (\bar{x}_{S_i}, \bar{y}_{S_i}), i = 1, 2, ..., n$ can be calculated by:

$$\bar{x}_{S_i} = (g_i + h_i + k_i)/3 \quad (3)$$

$$\bar{y}_{S_i} = \min(w_{ij})/3 \quad (4)$$

The distance between the centroid point $S_i = (\bar{x}_{S_i}, \bar{y}_{S_i}), i = 1, 2, ..., n$ and the minimum point $G = (x_{\min}, y_{\min})$, is determined by:

$$D(S_i, G) = \sqrt{(\bar{x}_{S_i} - x_{\min})^2 + (\bar{y}_{S_i} - \frac{\varpi}{3} y_{\min})^2} \quad (5)$$

where $x_{\min} = \min(g_i), y_{\min} = \min(w_{ij})$

Step 4: Defining the weight vector $W = (w_1, \ldots, w_n)^T$ of the fuzzy comparison matrix as:

$$w_i = \frac{D(S_i, G)}{\sum_{i=1}^{n} D(S_i, G)} = \frac{\sqrt{(\bar{x}_{S_i} - x_{\min})^2 + (\bar{y}_{S_i} - \frac{\varpi}{3} y_{\min})^2}}{\sum_{i=1}^{n} \sqrt{(\bar{x}_{S_i} - x_{\min})^2 + (\bar{y}_{S_i} - \frac{\varpi}{3} y_{\min})^2}}, \quad i = 1, \ldots, n \quad (6)$$

This study adopts a "Likert Scale" of fuzzy numbers to transform the linguistic values into TFNs, as shown in Table 1.

Table 1. Triangular fuzzy conversation scale (Anagnostopoulos et al., 2007)

Order	Linguistic values	Triangular fuzzy numbers	Reciprocal triangular fuzzy scale
1	Unimportant (U)	(1,1,1)	(1,1,1)
3	Slightly important (SL)	(2,3,4)	(1/4,1/3,1/2)
5	Moderately important (MI)	(4,5,6)	(1/6,1/5,1/4)
7	Seriously important (SI)	(6,7,8)	(1/8,1/7,1/6)
9	Very seriously important (VSI)	(8,9,9)	(1/9,1/9,1/8)

IV. Application of the fuzzy AHP approach to select and evaluate knowledge management system

In this section, Chang's (1996) fuzzy AHPapproach is applied to select and evaluate knowledge management system. Assuming that three decision makers (D1, D2, D3) are responsible for evaluate three knowledge management systems (A1, A2, A3) under six criteria: knowledge store (C1), knowledge map(C2), knowledge recommendation(C3), knowledge search (C4)and knowledge community(C5). Table 2 presents the averaged fuzzy comparison matrix of five criteriaassessed by the committee.

Table 2. Averaged fuzzy comparison matrix of five criteriaassessed by the committee

Criteria	C1	C2	C3	C4	C5
C1	(1.00, 1.00, 1.00)	(4.00, 5.00, 6.00)	(6.00, 7.00, 8.00)	(0.25, 0.33, 0.50)	(4.00, 5.00, 6.00)
C2	(0.17, 0.20, 0.25)	(1.00, 1.00, 1.00)	(2.00, 3.00, 4.00)	(0.13, 0.14, 0.17)	(2.00, 3.00, 4.00)
C3	(0.13, 0.14, 0.17)	(0.25, 0.33, 0.50)	(1.00, 1.00, 1.00)	(0.11, 0.13, 0.14)	(0.17, 0.33, 0.50)
C4	(2.00, 3.00, 4.00)	(6.00, 7.00, 8.00)	(7.00, 8.00, 9.00)	(1.00, 1.00, 1.00)	(8.00, 9.00, 9.00)
C5	(0.17, 0.20, 0.25)	(0.25, 0.33, 0.50)	(2.00, 3.00, 6.00)	(0.11, 0.11, 0.13)	(1.00, 1.00, 1.00)

Using Equations (2)-(6), the fuzzy synthetic extent values, the distance between the centroid point and the minimum point, and the weight vectors of criteria are calculated as in Table 3.

Table 3. Fuzzy synthetic extent values of five criteriaassessed by the committee

Criteria	Fuzzy synthetic extent values	Distance between the centroid point and the minimum point	Weights of criteria
C1	(0.22, 0.28, 0.36)	0.260	0.29
C2	(0.07, 0.09, 0.13)	0.073	0.08
C3	(0.02, 0.04, 0.05)	0.013	0.01
C4	(0.44, 0.53, 0.61)	0.504	0.57
C5	(0.04, 0.06, 0.09)	0.039	0.04

Table 4 presents the averaged fuzzy comparison matrix of three alternativesassessed by the committee under five criteria

Table 4. Averaged fuzzy comparison matrix of three alternativesassessed by the committee under five criteria

Criteria	Alternatives	A1	A2	A3
C1	A1	(1.00, 1.00, 1.00)	(2.08, 2.78, 3.50)	(2.06, 2.73, 3.42)
	A2	(0.81, 1.18, 1.58)	(1.00, 1.00, 1.00)	(1.39, 2.07, 2.75)
	A3	(1.47, 1.84, 2.25)	(1.50, 1.89, 2.33)	(1.00, 1.00, 1.00)
C2	A1	(1.00, 1.00, 1.00)	(2.75, 3.44, 4.17)	(1.44, 1.80, 2.17)
	A2	(0.78, 1.13, 1.50)	(1.00, 1.00, 1.00)	(0.25, 0.33, 0.50)
	A3	(2.72, 3.40, 4.08)	(2.00, 3.00, 4.00)	(1.00, 1.00, 1.00)
C3	A1	(1.00, 1.00, 1.00)	(1.47, 1.84, 2.25)	(3.33, 4.33, 5.33)
	A2	(2.06, 2.73, 3.42)	(1.00, 1.00, 1.00)	(0.50, 0.56, 0.67)
	A3	(0.19, 0.24, 0.33)	(1.67, 2.33, 3.00)	(1.00, 1.00, 1.00)
C4	A1	(1.00, 1.00, 1.00)	(0.81, 1.18, 1.58)	(1.50, 1.89, 2.33)
	A2	(2.08, 2.78, 3.50)	(1.00, 1.00, 1.00)	(3.42, 4.11, 4.83)
	A3	(1.39, 2.07, 2.75)	(0.76, 1.11, 1.47)	(1.00, 1.00, 1.00)
C5	A1	(1.00, 1.00, 1.00)	(0.83, 1.22, 1.67)	(2.71, 3.38, 4.06)
	A2	(1.42, 2.11, 2.83)	(1.00, 1.00, 1.00)	(0.76, 1.11, 1.47)
	A3	(2.11, 2.47, 2.83)	(3.42, 4.11, 4.83)	(1.00, 1.00, 1.00)

Using Equations (2)-(6), the fuzzy synthetic extent values, the distance between the centroid point and the minimum point, and the weight vectors of alternatives are calculated as in Table 5.

Table 5. Fuzzy synthetic extent values of three alternativesassessed by the committee under five criteria

Criteria	Alternatives	Fuzzy synthetic extent values	Distance between the centroid point and the minimum point	Average of alternatives
C1	A1	(0.32, 0.42, 0.52)	0.23	0.53
	A2	(0.19, 0.27, 0.37)	0.09	0.20
	A3	(0.23, 0.31, 0.40)	0.12	0.28
C2	A1	(0.30, 0.39, 0.49)	0.28	0.64
	A2	(0.11, 0.15, 0.22)	0.05	0.11
	A3	(0.36, 0.46, 0.56)	0.35	0.79
C3	A1	(0.38, 0.48, 0.57)	0.30	0.69
	A2	(0.22, 0.29, 0.37)	0.12	0.27
	A3	(0.17, 0.24, 0.32)	0.07	0.16
C4	A1	(0.19, 0.25, 0.34)	0.08	0.18
	A2	(0.39, 0.49, 0.59)	0.31	0.70
	A3	(0.18, 0.26, 0.35)	0.08	0.19
C5	A1	(0.25, 0.32, 0.41)	0.15	0.35
	A2	(0.17, 0.24, 0.32)	0.07	0.17

	A3	(0.35, 0.44, 0.53)	0.27	0.61

Table 6 presents the average weighted value of alternatives assessed by the committee under five criteria

Table 6. The average weighted value of alternatives assessed by the committee under five criteria

Criteria	**Alternatives**	**Average weighted value of alternatives**
C1	A1	0.53
	A2	0.20
	A3	0.28
C2	A1	0.64
	A2	0.11
	A3	0.79
C3	A1	0.69
	A2	0.27
	A3	0.16
C4	A1	0.18
	A2	0.70
	A3	0.19
C5	A1	0.35
	A2	0.17
	A3	0.61

Table 7presents the final values and ranking order of alternatives. The result shows that A2 is the best alternative.

Table 7. The final values and ranking order of alternatives

Alternatives	**Final values**	**Ranking order**
A1	0.33147	2
A2	0.47846	1
A3	0.27999	3

V. Conclusion

Selecting and evaluating knowledge management system is an important task of small and medium enterprises. This study applied the most recent fuzzy AHP approach to evaluate and select knowledge management system. A simulation examplewas used to clarify the application steps of the proposed model.The application steps of fuzzy AHP method include: (i) building a pairwise comparison matrix; (ii) determining the value of the fuzzy synthetic extent; (iii) calculating the weight vectors; (iv) ranking the alternatives.

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