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Evaluating Knowledge Management Tools on the Basis of Customization using Fuzzy Approach

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ABSTRACT

Today's world economy situation forces enterprise organizations toward more soft and flexible organization, management, and production processes. They need to explore the most suitable Knowledge Management (KM) tool not only to identify gaps and overlaps but also to maintain and support innovation cross organizations. In this study, a multiple-experts-multiple-criteria decision making model is developed in order to allow organizations to make the appropriate selection of KM tools that are the most likely to benefit their process innovation efforts. Also, the model aims to suggest conditions for the improvement of KM in different types of knowledge-based inter-organizational collaborations. The application of the model is demonstrated by an illustrative example.

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1. Introduction

Competition among enterprise organizations results in not only paying more attention and consideration to their internal and external resources, but also improving the performance by the recovery and reuse of resources. As a result, organizations need to select the most suitable Knowledge Management (KM) tool through a framework that identifies shortcomings and capabilities in the current KM tools portfolio. The KM tool aims at maintaining and supporting the innovation processes in the organization. Also, the KM objective is focused on performance, competitive advantage, innovation, sharing of lessons learned, and integration and continuous improvement of the organization. The knowledge flow is used to improve the organization in the areas of strategic management, organizational analysis and economics [1]. This can also be achieved through a KM model based on KM critical success factors and a systematic network model [2, 3].

The KM resources can be part of the human resource management or information technology department that is able to create knowledge that is both explicit and tacit. The knowledge that is gained from manuals and procedures is considered explicit knowledge, whereas the knowledge gained through experience and communication that is indirect is considered tacit knowledge.

Among the KM objectives, innovation known as something new or novel seems to be more invested [4,5,6]. The challenges to innovation stem from the 1- disagreement on a common definition, 2- the difficulty in comparing firms in term of innovation, and 3- the difficulty in quantifying innovation activities.

Companies that are frequently proficient at responding to changes in their environments and contain personnel that are creative and able to develop innovative products and services are considered innovative companies. Therefore, innovation within organizations requires the ability of personnel to be able to accept and adapt to change, while at the same time being able to control their creative abilities.

Furthermore, innovation can be characterized as the focus on and the interaction of user needs and organizations' technological opportunities [7]. Also, a number of studies have emphasized the importance of transformational leadership as a positive factor necessary for organizational innovation [7]. Therefore,

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effective leadership is an important factor that can positively influence innovation.

Further research conceptualized organizational innovation as organization's creating or improving their products or services and the success of their marketing efforts of these creations or improvements [8]. This literature suggests that support received from internal or external organizations for the purposes of knowledge and resource acquisition also provides a moderate relationship between transformational leadership and organizational innovation.

A wide range of methodologies and organizations with the common aim of delivering new products and services can be used [9]. For Example, a user-centered methodology encourages organizations to consider their core values, to identify opportunities based on their customers' needs and encourages new thinking based on a reevaluation of the organization's innovative culture. However, independent of approaches, many resources have been developed to help organizations choose KM tools for their innovation processes. These are generally based on a user-centered or ethnographical strategy.

Therefore, new knowledge construction, embodiment, and dissemination as well as knowledge's use and benefit may be byproducts of KM [10]. For an innovation to take place, an organization needs savvy people who not only are willing to share knowledge and experience for the greater good of the organization but also have the ability to turn ideas into practical and final products and services. Furthermore, in order for organization to be innovative and highly competitive within its market, it must be able to effectively use its knowledge and KM tools.

The understanding of the term "knowledge" and what it means to the individual or the organization is very important, because it affects how knowledge enters the managerial processes [11]. Knowledge is a complex term, since it is often not easy to agree on an exact definition. It is also accepted that there cannot be a single solution to the use of technology to support of KM in organizations. Further complicating this understanding is that it is difficult to determine what must be done to support innovation and what KM tools to use from one organization to the next, since KM tools differ and may be appropriate in one situation and not in another. As a result, organizations will need to carefully select the most appropriate KM for their specific organizational framework. Therefore, dealing with this complexity in managing innovation within an organization is a key role in KM.

Only a good leadership and a sound administration can provide all of these requirements for managing technology and innovation. Management focus has a significant effect on organizational innovation. The importance of the top managers' support of innovation at the work place was noted by previous studies [12]. Innovation is now viewed as the catalyst of organizational growth by various manufacturers. Knowledge that was once separate and distinct is now merged and combined in different ways [13]. This significant change in organizational practice is considered innovation, only when the combination of these separate and distinct domains of knowledge leads to new products and service and their successful diffusion [14, 15].

The performance of KM is a key to enhancing the service level of projects in organizations. Based on the characteristics of KM, a fuzzy evaluation system for the management performance of Knowledge that was based on Fuzzy Analytic Hierarchy Process (FAHP) was set up [16]. This work attempted to determine the key factors that affect success in selecting KM Tools for supporting innovation using FAHP. Additionally, it provides an evaluation method that helps researchers and managers to determine the drawbacks and opportunities for selecting a KM tool [16]. Similarly, to accomplish this objective, authors have proposed a methodological framework based on layer graphs that include multiple experts' opinions on decision criteria. Converting the multi-layer graph to a single graph by using a fuzzy conflict resolution method will reduce the decision complexity [17].

In this study, the authors cover scenarios and provide a framework to select the KM tools that support innovation processes within organizations. The methodological framework is based on iterative processes that include multiple experts' opinions of conflict resolution and a decision support technique called FAHP. The model uses a fuzzy conflict resolution approach to dilute the experts' opinions conflict in order to construct a pair-wise comparison matrix.

This matrix is a base for the next decision making process which takes into account the strategic intangible assets and the specific context of the company. Converting linguistic variables to Triangle Fuzzy Numbers (TFN), the framework uses the defined TFNs between several factors that affect the selection of the most appropriate KM tool to sustain an innovation process. Furthermore, the authors will pinpoint the most important criteria for selecting the most appropriate set of KM Tool. This is reached by applying the FAHP and exploring the solution of selecting the most appropriate set of KM tools.

2. Literature Review

An issue organizations face today is proper KM, since organizations have begun to realize the drawbacks of mishandling of knowledge and the mistakes that have resulted from such mishandling of organizational knowledge. Any knowledge developed within a company, is considered to be part of the company's assets, and should be managed in a manner similar to other assets. Furthermore, those who promote KM find it easier to identify areas where things are going wrong. Also, companies who do not provide a proper knowledge repository and an equally functional access method are likely to duplicate the production of knowledge leading to considerable inefficiency. It is not difficult to show that if certain knowledge is inaccessible, mistakes and wrong decisions can be made, and since there is no standard way of tracking these issues these mistakes can be repeated [18].

Actually, among the main difficulties experienced by organizations is their failure to manage decisions on finding the best KM tool. Therefore, conducting research on decision models for such a purpose becomes important. The KM tool selection problem requires that a decision maker chooses between alternatives associated with different consequences and different impacts.

Braybrooke and Lindblom [19] proposed constructing a matrix that represents relationships among results and problems associated with a made decision. A rationality-based model was developed that analyzed the decision making process through the Daft matrix [20].

Another decision approach is an evidence-based decision (EBD) that proposes founding managerial analysis, actions, and decisions on the best possible evidence. EBD is based on techniques derived from judgment, experience, and managerial abilities. EBD was derived from evidence-based medicine (EBM) for the field of management [21, 22, 23]. In 2010, a bifocal EBD model was reported that uses the information system of the company for making decisions [24]. EBD needs a systematic focus on the best external evidence with know-how and experience, which is known as a shortcoming of this method. This is because of the mechanism of knowing which decisions are satisfactory is not evident [24, 25].

Decision Analysis (DA) methods qualitatively evaluate alternatives through assessment of preferences that can be classified to 1) Single Objective Decision Making (SODM) [26], 2) Multiple Criteria Decision Making (MCDM) [27, 28], 3) Other Multiple Attribute Decision Making (OMADM) methods such as conjunctive and disjunctive methods, and Technique for Order Preference by Similarity to Ideal Situation (TOPSIS).

The MCDM methods identify a preferred course of actions for the decision maker [29]. These methods can be categorized into Multiple Attribute Decision Making (MADM) [30] and Multiple Objective Decision Making (MODM). In 2011, a hybrid MCDM approach was reported to rank the KM tools for adoption and achieve an aspired level of performance [31].

This hybrid method is made up of three elements: 1- Decision Making Trial and Evaluation Laboratory Technique (DEMATEL) [32], 2- Analytic Network Process (ANP), and 3- SAW VIKOR. To resolve interdependency among decision criteria, the ANP is proposed by [30] as an extension of Analytic Hierarchy Process (AHP). In 2007, an ANP model was introduced for selecting a proper KM strategy [33, 34, 35]. In 2008, a KM performance evaluation model was proposed. The model was established based on KM theory and the ANP performance assessment approach [36, 37].

However, the ANP is a complex process that requires more numerical calculations in order to evaluate priorities than that of the AHP [37]. Because of fuzzy criteria, Tsenga [31] demonstrated a framework that used the fuzzy set theory to interpret the linguistic information and the ANP to rank alternatives of KM strategies.

On the other hand, DEMATEL is used to make a network relationship map representing the interrelations among criteria [38, 39]. The TOPSIS is a distance-based method that uses the shortest and farthest distances from positive and negative ideal solutions to find the ranking of the alternatives [40]. The KM strategy selection was tackled by combined ANP and TOPSIS approaches [41]. These techniques also have been applied in a fuzzy environment [39]. Similar to TOPSIS, the SAW VIKOR method solves a multi-criteria decision making problem with non-commensurable and conflicting criteria to rank the KM tools based on the highest score [42].

The SODM also includes 1) Decision Tree [43], 2) Multiple Attribute Utility Theory (MAUT), and 3) AHP [33]. The AHP is used for multi criteria analysis that allows the representation of the interaction of various factors in a complex situation. In this method, a hierarchical structure is developed to represent the factors given in the KM tool selection problem. The decision maker then makes judgments on the importance of each factor over the other on the basis of the decision maker's preference [44]. Some studies also proposed FAHP that deals with evaluating uncertainty in judgment and decisions. For example, Chang [45] and Chi et al. [46] developed AHP models to explore the influence of KM tools in an organization.

In the next section, the potential scenarios are studied and an appropriate model is proposed to select the KM tools that support innovation processes within organizations.

3. Multiple-Experts-Multiple-Criteria KM Model

This study aims at developing a model that uses multiple experts' opinions for several criteria in order to select the best KM tool. However, the experts' opinions differ substantially because the experts do not often agree on the level of a specific criterion with respect to a specific KM tool. Therefore, having a conflict resolution Eq.(1) is considered in order to construct the comparison matrix used in FAHP.

$$A_{ij} = Min\lfloor MAX(Neg(I_k), C_{kij}) \rfloor \quad \forall k \tag{1}$$

where A_{ij} is aggregated value, I_k is importance/weight of expert k, and C_{kij} is a linguistic value assigned by expert k for comparing criterion i to criterion j.

Also, the authors propose the use of linguistic variable in Table 1 to express not only the level of criteria for each KM tool but also the weight of each expert. Also, Table 1 presents the TFN which corresponds to the linguistic variables.

Tab. 1. Equivalent of linguistic variable to triangular fuzzy number

Linguistic Variable	Neg	TFN
Absolute (A)	N	(7/2, 4, 9/2)
Very strong (VS)	VW	(5/2, 3, 7/2)
Strong (S)	W	(3/2, 2, 5/2)
Equal (E)	E	(1, 1, 1)
Weak (W)	S	(2/5, 1/2, 2/3)
Very Weak (VW)	VS	(2/7, 1/3, 2/5)
Non (N)	A	(2/9, 1/4, 2/7)

Figure 1 depicts the decision process in the model that is based on multiple experts' conflict resolution, conversation of linguistic variables to TFN, and FAHP.

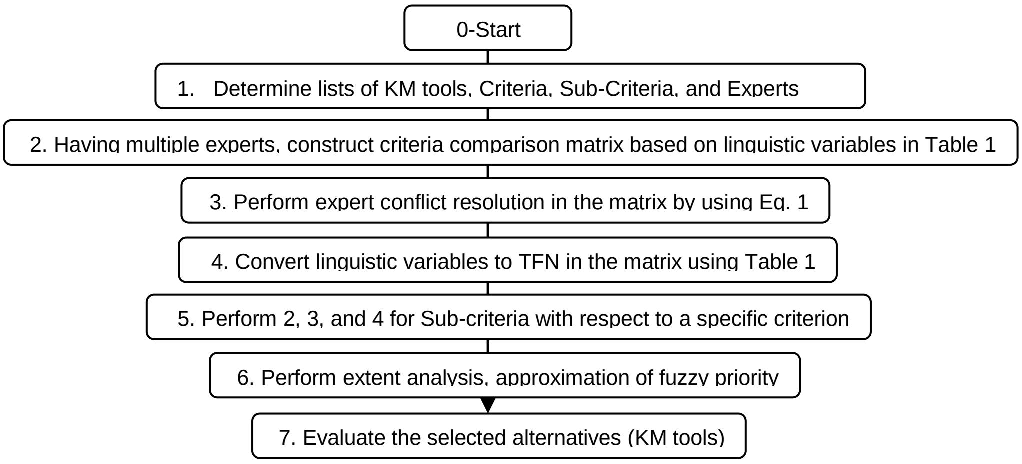

Fig. 1. Multiple-experts-multiple-criteria KM tool selection process

4. Identification of Criteria and KM Tools

The organization's KM success is dependent on organization's ability to select appropriate alternatives that align well with the organization's goals. Therefore, the most ideal organizational approach to this challenge is to pursue KM initiatives that address the organization's current situation, goals, and objectives and then pinpoint those initiatives that neatly fit into the organization's general solution. This should ultimately result in the organization's ability to support its goals and objectives. Table 2 presents the criteria used in KM tools. The criteria used to evaluate KM tools can be grouped into Knowledge improvement (C1), Performance Improvement (C2), and Network Improvement (C3) as Echt et al. [21] recommended in their paper and are explained as follows:

Tab. 2. Criteria used to evaluate KM tools

Notation	Criterion	Description
C1	Knowledge Improvements	C1 is the value creation capability of an organization through the resources owned by individuals. C1 goal is to generate new knowledge. Examples of the new knowledge include capabilities, know-how, expertise, and skills. Also, this category is concerned with the ability of personnel to generate value by using resources available to them. The aim is to distribute and share knowledge and to generate new knowledge. In this research, these are evaluated on the basis of their capability to support the innovation process, exploit new markets, and generate value adding processes.
C2	Performance improvements	C2 is the concept of measuring the output of a particular process or procedure, then modifying it to increase the output, increase efficiency, or increase its effectiveness. Attributes such as the characteristics of human-computer interfaces, ease of use, effectiveness of search mechanisms, and flexibility influence system quality. In a short-term organizational view, KM initiatives should be directly linked to explicit and important aspects of organizational, process, and human resource performance such as level of inter and intra-communication, time to market, cost savings, competitive positioning, and market shares.
C3	Network improvements	C3 refers to networks and communities that differ in a KM point of view. In this category, there is an addition of significant value in the creation and dissemination of knowledge, as well as the accelerated output and application of improved knowledge. KM initiatives can support networks of knowledge workers through all the internal and external relationships with stakeholders. The positive effects on these initiatives are a result of different organizations collaborating to move from incremental improvements to significant and radical change. This is accomplished through the combination of initiatives that once existed separate from one another in the various organizations. Furthermore, the distribution of risk and the sharing of resources are characteristic of this category. Therefore, knowledge networks formed in this manner are able to take advantage of the potential benefits of combined knowledge regardless of the location of information.

KM tools can be defined as a set of instruments that serves as a means for performing functions, processes, operations, or tasks in KM. It is generally accepted that there is no unique solution for the use of technology to support of KM in organizations. Therefore, different KM tools can be defined in different contexts and accordingly organizations should select the KM tools that are aligned to their goals. In this paper, the following KM tools are adopted for supporting innovation and are explained as follows:

Tab. 3. KM tools

Notation	KM Tool	Description
A1	Business intelligence	A1 refers to the use architectural and methodological sets that are meant to change raw data to more useful and meaningful information. It allows business users to make informed business decisions with real-time data that can put a company ahead of its competitors.
A2	Content applications	A2 is involved during the construction and dissemination process while having a set of technologies, digital information and documents.
A3	Data management tools	A3 Tools is included on the KM process during the construction and embodiment phase. It is gathered of structured collection of records or data that is stored in a computer system.

5. Fuzzy Analytic Hierarchy Process

The Analytic Hierarchy Process is a tool utilized by many researchers worldwide. It is a decision making process which helps to set priorities when a quantitative and qualitative aspect is being considered in an equation. Furthermore, many find it very practical and flexible to use. This process works by minimizing complex evaluation criteria into a series of one-to-one comparisons.

However, due to lack of certainty on information and difficulty evaluating strength of preferences, decision makers are unable to set the exact numerical values when conducting the test. Therefore, AHP plays a key role in solving this issue by enabling users to deal with vagueness and uncertainty in the decision process.

FAHP consists of local priority from preference ratio, which is combined to generate what is known as the global priorities. In this study, the FAHP computes fuzzy priorities based on arithmetic operations for trapezoid or triangle numbers. Although this system is widely known, there are many critics of this theory due to its consistency issue.

This is because there is no specific articulation on what would make up an inconsistent comparison matrix and how the information would be handled. Also, the obtained fuzzy priorities are more likely to be flawed due to its lacking of a mechanism to eliminate inconsistent data.

Therefore, the solution to the problem is adopted. The following steps are to be used in selecting a proper KM tool. According to Chang's method, each object is taken and the extent analysis for each goal is performed respectively [45].

Step 1: The value of fuzzy synthetic extent with respect to the i^{th} object is determined as:

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \oplus [\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}]^{-1} \tag{2}$$

To derive $\sum_{j=1}^{m} M_{gi}^{j}$, the fuzzy addition operation of m extent analysis values for the certain matrix is performed such as:

$$\sum_{j=1}^{m} M_{gi}^{j} = (\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j) \tag{3}$$

And to acquire $[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}]$, by performing the fuzzy addition operation of M_{gi}^{j} (=1,2,…,m) such that:

$$[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}]^{-1} = (\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j) \tag{4}$$

And $[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}]^{-1}$ can be calculated by the inverse of Eq.(4), as follows :

$$[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}]^{-1} = (\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}) \quad (5)$$

Step 2: as $M_1 = (l_1, m_1, u_1)$, and $M_2 = (l_2, m_2, u_2)$ are two triangular fuzzy numbers, the degree of possibility of $M_2 \geq M_1$ is defined as:

$$V = (M_2 \geq M_1) = \sup_{y \geq x}[\min(\mu_{M_1}(x), \mu_{M_2}(y))] \quad (6)$$

And can be equivalently expressed as follows:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_2}(d) = \begin{cases} 1 & if\ m_2 \geq m_1 \\ 0 & if\ l_2 \geq u_2 \\ \dfrac{(l_1 - u_2)}{(m_2 - u_2) - m_1 - l_1)} & Otherwise \end{cases} \quad (7)$$

Where d , as shown in Figure 2, is the ordinate of the highest intersection point D between μ_{M1} and μ_{M2}. To compare $M_1 = (l_1, m_1, u_1)$, and $M_2 = (l_2, m_2, u_2)$, we need both the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$.

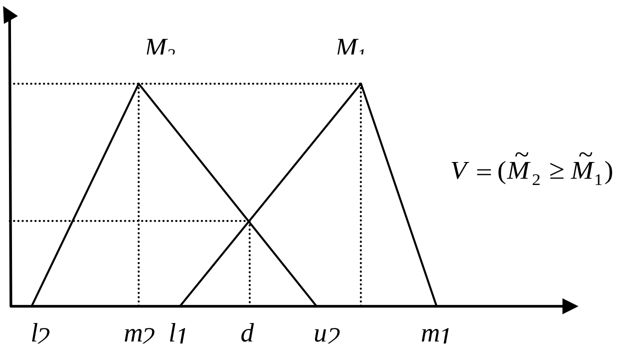

Fig. 2. Intersection between M_1 and M_2

Step 3: The degree possibility for a convex fuzzy number to be greater than k convex fuzzy M_i (i= 1,2,...,k) numbers can be defined by

$V(M \geq M_1, M_2, \ldots, M_k) = v[M \geq M_1\ and\ M \geq M_2\ and\ M \geq M_k] = \min v\ M \geq M_1, i = 1, 2, \ldots, k$ (8)

Assume that

$d'(A_i) = \min V\ (S_i \geq S_k)\ for\ k = 1,2,\ldots,n\ ; k \neq i$ Then the weight vector is given by

$$W' = (d'(A_1), d'(A'_2, \ldots, d'(A_n))^T \quad (9)$$

where A_i (i=1,2,…,n) are n elements.

Step 4: Via normalization, the normalized weight vectors are

$$w = (d\ (A_1),\ d\ (A_2), \ldots,\ d\ (A_n))^T \quad (10)$$

Where w is a non- fuzzy number.

6. An Illustrative Example

The hierarchy of the selection criteria and decision alternatives can be seen in Figure 3. In the hierarchy, the overall objective (i.e., the best KM tool) is placed at level 1, criteria at level 2, and the KM tools at level 3. In the output of the hierarchical structure, as presented in the Figure 3, all the criteria are arranged in such a way that each of them directly influences the selection of KM tools.

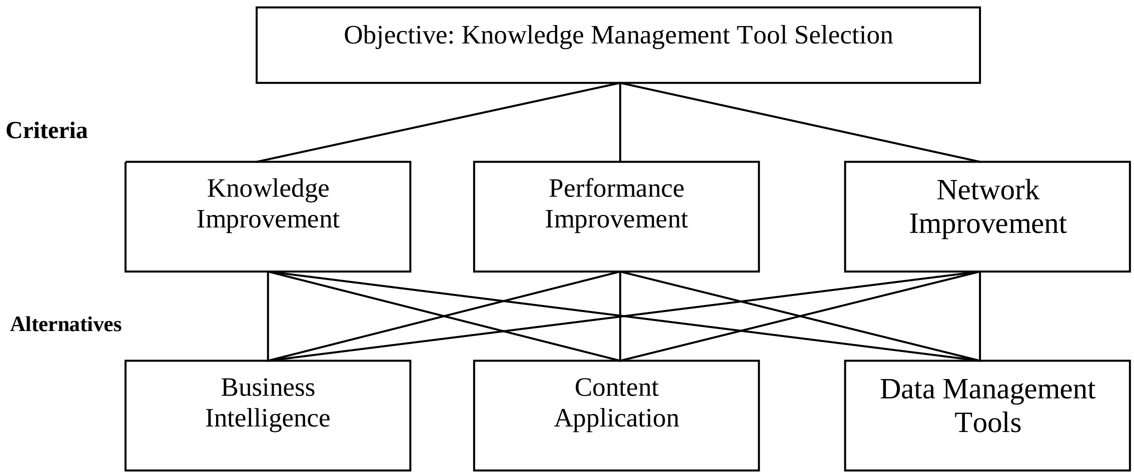

Fig. 3. Hierarchy for KM Tool Selection

6.1. Constructing the Multiple Expert-Multiple Criteria Comparison Matrix

The process starts by constructing pairwise comparison matrix for the criteria (C_1: Knowledge Improvement, C_2: Performance Improvement, C_3: Network Improvement), which consists of several fuzzy linguistic values obtained from experts as shown by ($A_{1ij}, A_{2ij},\ldots,A_{kij}$).

The expert k has its own weight (Importance) according to his experiences that is denoted by I_k.

For example, if the weight of criterion C_1 relative to criterion C_2 is (A, VS,E) by three experts whom their Importance are (E,E,S), the weight of C_2 relative to $C_1$is (N,VW,E). Then, we use Eq(1) to resolve the conflict among the experts. Therefore, the main weight of criterion C_1 relative to criterion C_2 is

$$Min\left[MAX\left(Neg(E), A\right), MAX\left(Neg(E), VS\right), MAX\left(Neg(S), E\right)\right] = E \quad (11)$$

Now, the main weight is converted to TFN by using Table 1. For example, the equivalent TFN for E is (1,1,1).

6.2. The FAHP Process

The pair wise comparison matrix of each category is assigned by relating the preference of the decision makers to the overall objective. The pair wise comparisons for the criteria are determined and shown in Table 4.

For identifying the computation procedures, the pair-wise judgments from the Table 4 are evaluated as follows:

$$S_1 = (4.5, 5, 6.5) \odot \left(\frac{1}{12.67}, \frac{1}{10.57}, \frac{1}{8.73}\right) = (0.36, 0.49, 0.71)$$

$$S_2 = (2.4, 3, 3.67) \odot \left(\frac{1}{12.67}, \frac{1}{10.57}, \frac{1}{8.73}\right) = (0.19, 0.27, 0.4)$$

$$S_3 = (1.83, 2.07, 2.5) \odot \left(\frac{1}{12.67}, \frac{1}{10.57}, \frac{1}{8.73}\right) = (0.15, 0.19, 0.27)$$

Tab. 4. Criteria fuzzy pair wise comparison matrix

Criteria	Knowledge Improvement	Performance Improvement	Network Improvement
Knowledge Improvement	(1,1,1)	(3/2,2,5/2)	(2,5/2,3)
Performance Improvement	(2/5,1/2,2/3)	(1,1,1)	(1,3/2,2)
Network Improvement	(1/3,2/5,1/2)	(1/2,2/3,1)	(1,1,1)

After determining these results, these fuzzy values are compared by using Eq. (7)

$$V(S_1 \geq S_2) = 1, V(S_1 \geq S_3) = 1,$$

$$V(S_2 \geq S_1) = \frac{0.07 - 0.333}{(0.1533 - 0.333) - (0.2851 - 0.07)} = 0.15$$

$$V(S_2 \geq S_3) = 1, V(S_3 \geq S_1) = 1$$

$$V(S_3 \geq S_2) = \frac{0.07 - 0.333}{(0.1533 - 0.333) - (0.2851 - 0.07)} = 0.5$$

Then priority weights are calculated by using Eq. (8):

$$d'(Knowledge\ Improvement) = V(S_1 \geq S_2, S_3) = \min(1,1,1) = 1$$

$$d'(Performance\ Improvement) = V(S_2 \geq S_1, S_3) = \min(0.15, 1) = 0.15$$

$$d'(Network\ Improvement) = V(S_3 \geq S_1, S_2) = \min(0, 0.5) = 0$$

After the weight vector is calculated, the normalization of these values that show the priority weights for the criteria are calculated in Table 5.

Tab. 5. The priorities weights for criteria

Criteria	W'	W
Knowledge Improvement	1	0.87
Performance Improvement	0.15	0.13
Network Improvement	0	0

The same systematic approach is considered for the other evaluations, and priority weights for the criteria with respect to the Business Intelligence are determined and shown in Table 6.

Tab. 6. Alternative fuzzy pair wise comparison matrix with respect to Knowledge Improvement

Knowledge Improvement	Business Intelligence	Content Application	Data Management Tools
Business Intelligence	(1 , 1 , 1)	(3.13 , 6.7 , 4.8)	(0.31,0.83,0.46)
Content Application	(0.21,0.15,0.32)	(1 , 1 , 1)	(3.13 , 6.7 , 4.8)
Data Management Tools	(2.2,1.2,3.25)	(0.21,0.15,0.32)	(1 , 1 , 1)

$$S_1 = (4.43, 8.53, 6.26) \odot \left(\frac{1}{16.945}, \frac{1}{18.372}, \frac{1}{12.174}\right) = (0.262, 0.456, 0.514)$$

$$S_2 = (4.33, 7.849, 6.12) \odot \left(\frac{1}{16.945}, \frac{1}{18.372}, \frac{1}{12.174}\right) = (0.256, 0.419, 0.503)$$

$$S_3 = (3.408,2.349,4.57) \odot (\frac{1}{16.945},\frac{1}{18.372},\frac{1}{12.174}) = (0.201,0.125,0.375)$$

$$V(S_1 \geq S_2) = 1$$

$$V(S_1 \geq S_3) = 1$$

$$V(S_2 \geq S_1) = \frac{0.262-0.503}{(0.419-0.503)-(0.456-0.262)} = 0.868$$

$$V(S_2 \geq S_3) = 1$$

$$V(S_3 \geq S_1) = \frac{0.262-0.375}{(0.1254-0.375)-(0.456-0.262)} = 0.255$$

$$V(S_3 \geq S_2) = \frac{0.256-0.375}{(0.125-.0375)-(0.419-0.256)} = 0.288$$

$$d'(Business\ Intelligence) = V(S_1 \geq S_2, S_3) = \min(1,1) = 1$$

$$d'(Content\ Application) = V(S_2 \geq S_1, S_3) = \min(0.868,1) = 0.868$$

$$d'(Data\ Management\ Tools) = V(S_3 \geq S_1, S_2) = \min(0.255,0.288) = 0.255$$

Using Eq.(9) to calculate and after normalization of these values priority weights with respect to Business Intelligence are shown in Table 7.
Following the same process, the priority weights for the criteria with respect to the Content Application are determined and shown in Table 8.

Tab. 7. The weights of criteria with respect to Knowledge Improvement

Knowledge Improvement	W'	W
Business Intelligence	1	0.471
Content Application	0.868	0.409
Data Management Tools	0.255	0.120

Tab. 8. Alternative fuzzy pairwise comparison matrix with respect to Performance Improvement

Performance Improvement	Business Intelligence	Content Application	Data Management Tools
Business Intelligence	(1 , 1 , 1)	(4.75 , 2.9 , 3.5)	(0.293,0.147,0.172)
Content Application	(0.286,0.345,0.211)	(1 , 1 , 1)	(7.4,5.2,1.6)
Data Management Tools	(5.82,6.79,3.41)	(0.625,0.192,0.135)	(1 , 1 , 1)

$$S_1 = (6.043,4.047,4.672) \odot (\frac{1}{12.027},\frac{1}{18.574},\frac{1}{22.174}) = (0.50,0.22,0.21)$$

$$S_2 = (8.686,6.545,2.811) \odot (\frac{1}{12.027},\frac{1}{18.574},\frac{1}{22.174}) = (0.72,0.35,0.13)$$

$$S_3 = (27.445,7.982,4.545) \odot (\frac{1}{12.027},\frac{1}{18.574},\frac{1}{22.174}) = (0.62,0.43,0.2)$$

$$V(S_1 \geq S_2) = \frac{0.50-0.13}{(0.35-0.13)-(0.22-0.50)} = 0.74$$

$$V(S_1 \geq S_3) = \frac{0.50-0.20}{(0.43-0.2)-(0.22-0.50)} = 0.588$$

$$V(S_2 \geq S_1) = \frac{0.50-0.13}{(0.35-0.13)-(0.22-0.50)} = 0.74$$

$$V(S_2 \geq S_3) = \frac{0.72-0.2}{(0.43-0.2)-(0.35-0.72)} = 0.867$$

$$d'(Business\ Intelligence) = V(S_1 \geq S_2, S_3) = \min(0.74, 0.588) = 0.588$$

$$d'(Content\ Application) = V(S_2 \geq S_1, S_3) = \min(0.74, 0.867) = 0.74$$

$$d'(Data\ Management\ Tools) = V(S_3 \geq S_1, S_2) = \min(0.588, 0.867) = 0.588$$

Eq.(9) is used to calculate the priority weights with respect to content application in the Table 9.

Tab. 9. The weights of criteria with respect to performance Improvement

Performance Improvement	W'	W
Business Intelligence	0.588	0.307
Content Application	0.74	0.386
Data Management Tools	0.588	0.307

Priority weights for criteria with respect to the Network Improvement are determined and shown in Table 10.

Priority weights for criteria with respect to the Network Improvement are determined and shown in Table 10.

Tab. 10. Fuzzy pair wise comparison matrix with respect to Data Management Tools

Network Improvement	Business Intelligence	Content Application	Data Management Tools
Business Intelligence	(1 , 1 , 1)	(4.78 , 2.21 , 6.83)	(0.571 , 0.424 , 0.210)
Content Application	(0.286 , 0.345 , 0.211)	(1 , 1 , 1)	(4.54 , 1.12 , 3.55)
Data Management Tools	(5.82 , 6.79 , 3.41)	(0.625 , 0.192 , 0.135)	(1 , 1 , 1)

$$S_1(6.351,3.624,8.04) \odot (\frac{1}{15.77},\frac{1}{10.459},\frac{1}{18.09}) = (0.40,0.35,0.44)$$
$$S_2 = (5.67,2.572,4.759) \odot (\frac{1}{15.77},\frac{1}{10.459},\frac{1}{18.09}) = (0.36,0.250.26)$$
$$S_3 = (6.05,4.253,2.97) \odot (\frac{1}{15.77},\frac{1}{10.459},\frac{1}{18.09}) = (0.38,0.40,0.16$$
$$V(S_1 \geq S_2) = 1$$
$$V(S_1 \geq S_3) = \frac{0.40-0.16}{(0.41-0.16)-(0.35-0.40)} = 0.8$$
$$V(S_2 \geq S_1) = \frac{0.40-0.26}{(0.25-0.26)-(0.35-0.40)} = 2.8$$
$$V(S_2 \geq S_3) = \frac{0.36-0.16}{(0.4-0.16)-(0.25-0.36)} = 0.57$$
$$V(S_3 \geq S_1) = \frac{0.40-0.16}{(0.41-0.16)-(0.35-0.40)} = 0.8$$
$$V(S_3 \geq S_2) = \frac{0.36-0.16}{(0.4-0.16)-(0.25-0.36)} = 0.57$$
$$d'(Business\ Intelligence) = V(S_1 \geq S_2,S_3) = \min(1, 0.8) = 0.8$$
$$d'(Content\ Application) = V(S_2 \geq S_1,S_3,) = \min(2.8, 0.57) = 0.57$$
$$d'(Data\ Management\ Tools) = V(S_3 \geq S_1,S_2) = \min(0.8, 0.57) = 0.57$$

Table 11 shows the priority weights with respect to Data Management Tool.

Tab. 11. The weights of alternatives with respect to Data Management Tools

Network Improvement	W'	W
Business Intelligence	0.8	0.412
Content Application	0.57	0.294
Data Management Tools	0.57	0.294

6.3. Case Study Results

The priority of Knowledge Improvement is the most important criterion from the Table 5. In addition, in Table 12, the priority weight of each KM tool with respect to each criterion is displayed. For calculation, the final weight is obtained by multiplying the overall weight, for each alternative weight with respect to all criteria, with the priorities weights of criteria in Table 5.

Tab. 12. The priorities weights of suppliers with respect to all criteria

Criteria	Business Intelligence	Content Application	Data Management Tools
Knowledge Management	0.471	0.307	0.412
Performance Improvement	0.409	0.386	0.294
Network Improvement	0.120	0.307	0.294

Hence, the final weight matrix are summarized and displayed in Table 14. From the final ranking of all alternatives, the decision maker would consider alternative 1 over alternatives 2 and 3.

Tab. 14. The priority weights of the KM Tools

KM Tools	Final score
Business Intelligence	0.450
Content Application	0.405
Data Management Tools	0.145

7. Conclusion

The Analytical Hierarchy Process approach can be utilized in decision making problems. Although AHP theory is found ineffective in minimizing the ambiguity and uncertainty of the information, it can be relatively helpful when used to determine the relative weights given to different criteria. Furthermore, it can be a useful tool in determining the impact that each alternative would make on the focused attributes. In this study, an extended FAHP model is reported for the improvement of KM in different types of knowledge-based inter-organizational collaborations. The model uses three main criteria associated with the degree of preference. A case study was presented to demonstrate the application of the model. The results show the business intelligence is the best tools for improving the KM in an organization. For future works, one may develop a graph-based model to find the best tools and perform a comparative analysis.

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