Applying the Fuzzy Analytic Network Process to Establish the Relative Importance of Knowledge Sharing Barriers

Van Dong Phung, Igor Hawryszkiewycz, Kyeong Kang, Muhammad Hatim Binsawad

***Abstract*—**Knowledge sharing (KS) is the key to creativity and innovation in any organizations. Overcoming the KS barriers has created new challenges for designing in dynamic and complex environment. There may be interrelations and interdependences among the barriers. The purpose of this paper is to present a review of literature of KS barriers and impute the relative importance of them through the fuzzy analytic network process that is a generalization of the analytical hierarchy process (AHP). It helps to prioritize the barriers to find ways to remove them to facilitate KS. The study begins with a brief description of KS barriers and the most critical ones. The FANP and its role in identifying the relative importance of KS barriers are explained. The paper, then, proposes the model for research and expected outcomes. The study suggests that the use of the FANP is appropriate to impute the relative importance of KS barriers which are intertwined and interdependent. Implications and future research are also proposed.

***Keywords*—**FANP, ANP, knowledge sharing barriers, knowledge sharing, removing barriers, knowledge management.

I. Introduction

THE paper describes ways that the relative importance of KS barriers can be imputed by the fuzzy analytic network process (FANP). The study identifies the most critical barriers to KS through an examination of the research done by numerous authors over the past few decades. By using the FANP approach, the research proposes a method to establish the relative importance of barriers that will help to find ways to remove barriers and lead to increased creativity and innovation in organizations. The study will contribute to enhancing understanding of KS barriers and provide a method to establish the relative importance of KS barriers.

KS is the key to creativity and innovation in any organizations in which they have struggled to increase the KS among individuals. Overcoming the barriers has become a major driver for the potential success in knowledge management practices [5], [6], [16]. KS can be defined as a social interaction culture. Through it, knowledge, skills, and experiences are exchanged among individuals in the whole department or organization [7]. Identifying the relative importance of barriers which impede KS between people contributes to the critical debate among academics and practitioners.

This study focuses on applying the FANP to establish the weights of factors (aspects of barriers)/sub-factors (barriers) that are required for imputing the relative importance of KS barriers in order to improve KS.

II. The Aim and Research Question

A. The Aim of the Study

The main purpose of this study is to propose a model to apply FANP to establish the relative importance of KS barriers. This will help managers to prioritize the KS barriers and find ways to remove them in order to improve KS in organizations.

B. Research Question

How does the FANP model help to establish the relative importance of KS barriers in organization?

III. KS Barriers

KS barriers are all the factors that impede KS between/ among individuals, teams and organizations [14], [20]. A better understanding of these barriers is imperative need in order to encourage KS. A number of KS barriers were found through literature review. There were then categorized separately into several themes, although many of them are intertwined [14]. The study will adopt individual, organization and technology as three primary themes of barriers, as categorized by Riege [14]. Riege's categorization is a useful method to examine barriers because this method consists of the integral components of knowledge management and also makes it easier to gain a holistic understanding of KS [11].

The Critical KS Barriers:

This study examines the most critical barriers based on Riege and Muhammad and a literature review as shown in Fig. 1 [14], [16]. These barriers will be discussed in the following sub-sections:

A. Individual Barriers

- Knowledge hoarding [4], [41]-[46]

Knowledge hoarding refers to the act of accumulating knowledge that may or may not be shared later on. The perceived knowledge hoarding may result in difficult relationships between organizational members. It impedes sharing knowledge between colleagues. The reasons why people hoarding knowledge are fear of hosting "knowledge parasites", protection of individual competence, uncertainty

Van Dong Phung, Igor Hawryszkiewycz and Kyeong Kang are with The University of Technology, Sydney, Australia (e-mail: dongpv@gmail.com, igor.Hawryszkiewycz@uts.edu.au, Kyeong.Kang@uts.edu.au).

Muhammad Hatim Binsawad is with The King Abdulaziz University, Saudi Arabia (e-mail: Muhammad.Binsawad@student.uts.edu.au).

aversion, reluctance of spending time, avoidance of exposure, and compliance to hierarchy and formal power. Furthermore, knowledge hoarders believe that sharing may decrease or jeopardize their personal job security.

- Lack of a motivation [1], [2], [4], [5], [8], [12], [13], [17]

Motivation influences the KS behaviors of individuals. Some individuals may not anticipate reciprocal profits from sharing their knowledge. Lack of motivation has been recognized as a significant barrier to KS even when organizations provide all required conditions such as organization commitment, top management support, IT infrastructure, and technical support.

- Lack of trust [1], [3], [8], [10], [12], [14], [17]-[19]

KS is impossible without considering the word trust, as most individuals are unlikely to share their knowledge if they do not trust the person or organization that they are to share it with. Thus, several studies on KS indicated that lack of trust among people is the biggest barrier that impedes individuals from sharing knowledge with each other in an organization. Interpersonal distrust inhibits intra- and inter-organizational KS. Individuals may misuse knowledge or take unjust credit for it, leading to lack of trust among them.

B. Organization Barriers

- Lack of reward systems [1]-[3], [9], [12], [14], [17], [18]

Although an organization may support KS by providing top management support, a good organizational structure and good IT infrastructure, KS activities could be unsuccessful due to the lack of a transparent rewards and recognition systems.

- Lack of organization culture [1], [11], [12], [14], [18]

According to Anand et al. [1], "Organizational culture defines the core beliefs, values norms and social customs that govern the way individuals act and behave in an organization." Individuals share their knowledge socially (e.g., through unofficial discussion, social networks, face-to-face interaction, and personal relationships). Lack of organizational culture, that is an existing collective culture, does not deliver adequate support for KS practices and will eliminate KS because it is primarily based on organizational culture.

- Lack of leadership [2], [8], [12], [14]

Lack of leadership and managerial direction in terms of clearly communicating the benefits and values of KS practices and the presence of poor leadership hinders the successful sharing and transfer of knowledge in an organization.

C. Technology Barriers

- Lack of technical support [8], [10], [11], [14], [17], [18]

Lack of technical support is a barrier to knowledge creation, distribution, storage, application and with organizational learning because the lack of technical support may block communication flows and work routines and procedures.

- Insufficient technology infrastructure supporting KS [1], [4], [8], [10], [13], [17], [18]

The lack of technology infrastructure to support KS is a barrier to KS as it may discourage the successful sharing of knowledge. KS's high cost and the limitations of IT have proved to be a hindrance to people in sharing their knowledge in the organization.

Fig. 1 The most critical KS barriers

IV. A Review of Identifying KS Barriers and Gap Analysis

Our review of the literature to date has also covered approaches to identify and prioritize KS barriers in order to remove these barriers in many ways.

Firstly, various studies focused on identifying barriers to build on existing theory of KS barriers [4], [8]-[12], [14]. For example, Riege identified KS barriers in three domains: individual, organization, and technology [14]. The extensive list of potential barriers provided individual barriers, organizational barriers, technological barriers categorized based on the literature review and the opinions of experts from both academia and industry to accomplish the successful KS strategies in organizations. Following the Riege's study, many authors applied this result as a theory in which KS barriers can be seen as three domains; namely, organization, technology and individual, for many purposes. However, the barriers in Riege's study were not analyzed for their relationships and mutual influences.

Secondly, some authors identified and recognized the critical KS barriers and their mutual influences by modeling them, thus determining the driving and dependent barriers [1], [17]. The authors carried out these studies to identify the mutual influences among the critical barriers by using the interpretive structural modeling (ISM) approach. The results showed that two barriers, lack of top management commitment and knowledge management, are not well understood and have the highest driving power. Thus, these barriers need greater attention from top management if they want to improve KS. The strength of this approach is that the model of KS barriers can show the interrelationships among the various barriers. The limitation of the ISM approach is that the model is not statistically validated and can only consider a limited number of variables [21]. Another weakness of the ISM is that it does not examine the inner-outer dependences between barriers.

Finally, there has been little research in developing strategies to overcome barriers based on the relative importance of barriers [5]. Hong, Suh and Koo investigated KS bottlenecks and proposed the use of conversational KS based on community of practice and Web 2.0 to remove barriers in a financial company [5]. House of quality was applied to seek the solutions for overcoming the KS barriers. In this study, the authors used the AHP to analyze the relative importance of barriers by doing the pairwise comparisons that examine the interrelationship between enablers and barriers. Like the ISM approach, the AHP does not examine the inner-outer dependences between barriers, while according to Lin barriers are intertwined [7]. Hence, ANP is more useful than AHP for evaluating and ranking the relative influence of dimensions and criteria (barriers) [27].

From the above analysis it is clear that KS barriers have been identified and examined from different ways. Barriers are identified separately, in spite of the fact that there may be intertwined and interrelated [14]. Consequently, ANP, an extension of the AHP analyzed complex systems, is proposed to solve the problem of dependence among barriers. It is used to establish the relative importance of KS barriers. Furthermore, while measuring the barriers, we may encounter the limitations or difficulties [23]. For example, it is not possible to measure qualitative factors (barriers) including lack of trust, lack of motivation, lack of top management support, lack of organizational culture, and so on. Therefore, measuring barriers by applying fuzzy numbers instead of using crisp numbers allows more realistic results to be obtained [23]. Thus, the FANP is applied to establish the weights of factors/sub-factors which are required for imputing the relative importance of KS barriers to help practitioners and researchers find ways to remove the barriers.

V. Fuzzy Analytical Network Process (FANP)

A. Introduction to FANP

The AHP was first introduced by Saaty in 1980 [40]. It is widely used for solving complex decision-making problems as the multi-criteria decision technique [23], [24]. The AHP with its basic assumption is the condition of functional independence of the upper part, the hierarchy, from its lower parts, and the criteria or items in each level [23]. Many decisions problems cannot be structured hierarchically because they involve the interaction and dependence of higher level elements in a hierarchy on lower level elements [24]-[26]. While the AHP solves the problem of independence among alternatives or criteria, the ANP solves the problem of dependence among alternatives or criteria [26], [28]. Therefore, the AHP with its dependence assumptions on clusters and elements is a special case of the ANP [28].

The ANP is a combination of two parts. The first part is a control hierarchy or network of criteria and sub-criteria that controls the interactions. The second one is a network of influences among the clusters and elements [28]. The network differs from a criterion to a criterion, and a different supermatrix of influence is imputed for each control criterion. In summary, based on the priority of its control criterion and the results, each supermatrix is weighted [28].

The structural difference between a hierarchy and a network processes is illustrated in Fig. 2. A hierarchy consists of a goal, criteria, sub-criteria and alternatives. A hierarchical model imposes a linear structure. Unlike a hierarchy, a network spreads out in all directions and its clusters of elements (outer-dependence) and loops a cluster to itself (inner-dependence) [26], [30]. Outer-dependence is the dependence between elements for feedback circuits, while inner-dependence is the interdependence within an element combined with feedback between elements [29].

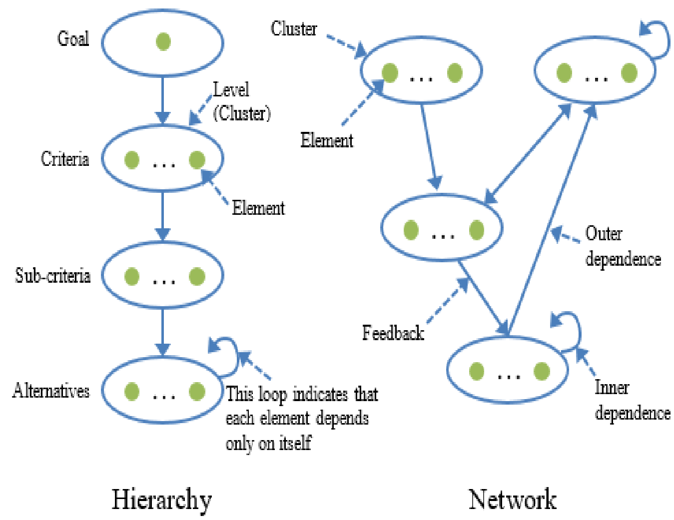

Fig. 2 Structural differences between a hierarchy and a network, adapted from [30]

There are several advantages of the ANP [28]:

- Allowing for interrelationships and interdependence;
- Making possible the representation of any decision problem without concern for what comes first or next as in a hierarchy based on the looser network structure;
- Being a nonlinear structure;
- Prioritizing not just elements but also groups or clusters of elements;
- Being a real world representation of the problem by making use of the clusters;
- Allowing consideration of tangible and intangible criteria in decision-making.

In spite of these advantages, however, the ANP has some disadvantages as well [31], [32]:

- Requires extensive brainstorming sessions in identifying attributes;
- Ignores the subjectivity of the comparisons;
- Acquires data is a time intensive process;
- Requires more intensity in calculating compared to the AHP.

There have been a number of research studies that incorporate the fuzzy set theory with the ANP method in order to eliminate the disadvantages of the ANP. In 2007, Ramik applied the logarithmic least squares method to integrate the fuzzy pair-wise comparisons and fuzzy extension of the ANP, and a feedback between the criteria [33]. This method is used to address problems in uncertain and complex environments. Mikhailov and Singh introduced the FANP approach to eliminate the subjectivity by combining the fuzzy set with the

ANP [34]. This combined method helps to solve the problems in dynamic and complex environment in which descriptions of environment, elements and judgments are subjective, vague, and imprecise by the nature [30], [31], e.g. the use of qualitative evaluation criteria that is the case in expert decision making. It may result in the decision makers clarifying the similar information from different ways [30]. Accordingly, many authors carry out the research in using the fuzzy set theoretical approach which can deal with these issues. Another study was carried out by Kahraman et al. [35]. This study was used as an extent analysis of Chang's method proposed for the fuzzy AHP method by considering the inner-dependence between the criteria.

B. The Fuzzy Set Theory

The fuzzy set theory was first introduced in 1965 by Zadeh [36]. It is widely used to deal with the uncertainty due to imprecision and vagueness [23]. The fuzzy can be referred to the situation that no boundary for the set of judgments or observations can be well defined [30]. The strong point of the fuzzy set theory is to represent vague data and enable mathematical operators and programming use to the fuzzy field [23].

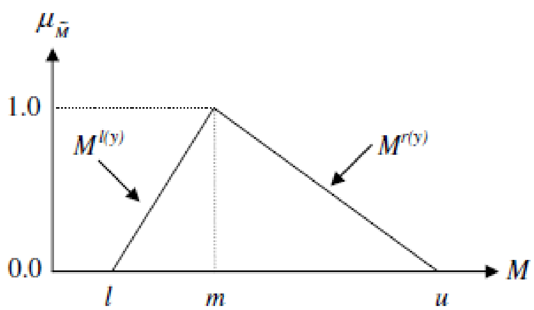

Fig. 3 A triangular fuzzy number, $\tilde{M}$ [23]

In the flowing section, we advance outlines for some basic definitions of fuzzy sets, triangular fuzzy numbers before going into the details of the proposed model.

Definition 1. A fuzzy set is a class of objects with a continuum of grades of membership. Such a set is characterized by a membership (characteristic) function, which assigns to each object a grade of membership ranging between zero and one [36].

Definition 2. A triangular fuzzy number (TFN) which can be denoted as $\tilde{M} = (l, m, u)$ is shown in Fig. 3. A TFN is denoted simply as (*l*/*m*/*u*) or (*l*,*m*,*u*). The parameters *l*, *m* and *u*, respectively, denote the smallest possible value, the most promising value, and the largest possible value that describes a fuzzy event. Each TFN has linear representations on its left and right side such that its membership function can be defined as [23]:

$$\mu_{\tilde{M}}(x) = \begin{cases} 0, x < l \text{ or } x > u \\ (x-l)/(m-l)\; l \le x \le m \\ (u-x)/(u-m),\; m \le x \le u \end{cases} \tag{1}$$

Definition 3. A fuzzy number can always be given by its corresponding left and right representation of each degree of membership [23]:

$$\tilde{M} = (M^{l(y)}, M^{r(y)}) = (l + (m-l)y, u + (m-u)y), y \in [0,1] \tag{2}$$

where *l(y)* and *r(y)* denote the left side representation and the right side representation of a fuzzy number, respectively.

C. Outline of the Computing Procedure of the FANP

There are several fuzzy ANP methods suggested in the literature. This study will apply the Chang's extent analysis method [37], [38]. The steps of this approach are other FANP approaches [30], [31].

The four main steps of the FANP based on Chang's extent analysis approach are explained as follows:

Let $X = \{x_1, x_2, \ldots, x_n\}$ be an object set, and $U = \{u_1, u_2, \ldots, u_m\}$ be a goal set. According to the method of Chang's extent analysis [38], each object is taken and extent analysis for each goal, g_i, is performed, respectively. Therefore, *m* extent analysis values for each object can be obtained, with the following signs:

$$M_{gi}^1, M_{gi}^2, \ldots, M_{gi}^m, \qquad i = 1, 2, \ldots, n \tag{3}$$

where all the M_{gi}^j $(j = 1, 2, \ldots, m)$ are TFNs.

The steps of Chang's extent analysis can be given as:

– <u>*Step 1:*</u> The value of fuzzy synthetic extent with respect to the i^{th} object is defined as:

$$S_i = \sum_{j=1}^{m} M_{gi}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j \right]^{-1} \tag{4}$$

To obtain $\sum_{j=1}^{m} M_{gi}^j$, perform the fuzzy addition operation of *m* extent analysis values for a particular matrix such that

$$\sum_{j=1}^{m} M_{gi}^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right) \tag{5}$$

and to obtain $[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j]^{-1}$, perform the fuzzy addition operation of M_{gi}^j $(j = 1, 2, \ldots, m)$ values such that

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i \right) \tag{6}$$

and then compute the inverse of the vector in (6) such that

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i} \right) \tag{7}$$

– <u>*Step 2:*</u> The degree of possibility of

$M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is defined as

$$V(M_2 \geq M_1) = \sup[\min(\mu_{M_1}(x), \mu_{M_2}(y))] \quad (8)$$

and can be equivalently expressed as:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_2}(d) = \begin{cases} 1, & \text{if } m_2 \geq m_1 \\ 0, & \text{if } l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & \text{otherwise,} \end{cases} \quad (9)$$

where d is the ordinate of the highest intersection point D between M_1 and M_2 (see Fig. 3).

To compare M_1 and M_2, we need both the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$.

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

$$V(M \geq M_1, M_2, \ldots, M_k) = V[(M \geq M_1) \text{ and } (M \geq M_2) \ldots \text{ and } (M \geq M_k)] = \min V(M \geq M_i), i = 1,2,\ldots,k \quad (10)$$

assume that

$$d'(A_i) = \min V(S_i \geq S_k) \quad (11)$$

For $= 1,2,\ldots,n; k \neq i$. Then, the weight vector is given by

$$W' = (d'(A_1), d'(A_2), \ldots, d'(A_n))^T, \quad (12)$$

where A_i $(i = 1,2,\ldots,n)$ are n elements.

– *Step 4:* Via normalization, the normalized weight vectors are:

$$W = (d(A_1), d(A_2), \ldots, d(A_n))^T, \quad (13)$$

where W is a nonfuzzy number.

D. The Model for Establishing Relative Importance of KS Barriers

This proposed model to establish the relative importance of KS barriers is adapted from the model proposed by Dağdeviren et al. [23]. There are several steps of the model as shown in Fig. 4.

- *Step 1:* Identify the critical barriers: This step will identify the critical barriers based on literature review and the expert's opinions. These barriers will be used in the model in step 2.
- *Step 2:* Structure the ANP model hierarchically (goal, criteria, sub-criteria).

The ANP model proposed consist of three levels as illustrated in Fig. 5. The goal is to determine the index weight in the first level. The level 2 represents the aspects of barriers (criteria). For example, individual barriers, organizational barriers, and technological barriers are three most important aspects of barriers based on Riege [14]. The level 3 represents barriers (sub-criteria). For instance, lack of trust, lack of motivation, lack of leadership, and lack of technical support are critical barriers [14]. The aspects (1, …, n) of second level are connected to the goal *"Weighting KS Barriers"* with a single directional arrow. The arrows in second level represent the inner-dependence among these aspects.

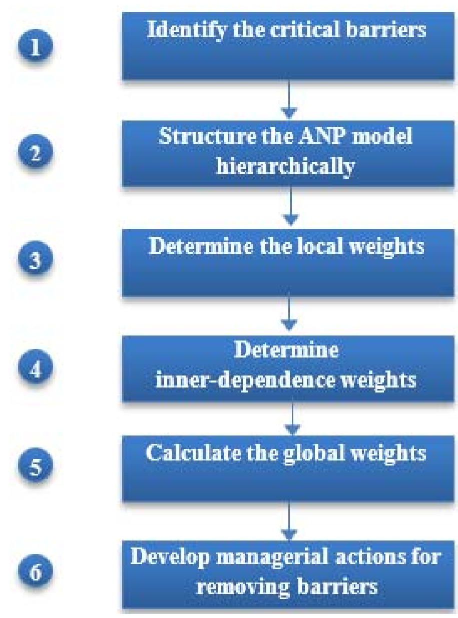

Fig. 4 The steps of the proposed model for establishing the relative importance of KS barriers.

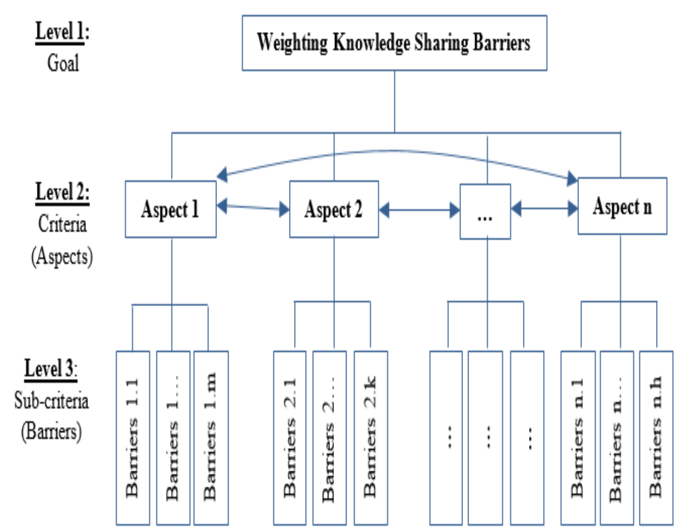

Fig. 5 The ANP model to establish the relative importance of KS barriers

- *Step 3:* Determine the local weights: This step is to determine the local weights of the criteria (aspects) and sub-criteria (barriers) by using pairwise comparison matrices. The fuzzy scale regarding relative importance to measure the relative weights is given in Fig. 6 and Table I [35]. This scale will be used to establish the local weights of criteria and sub-criteria.

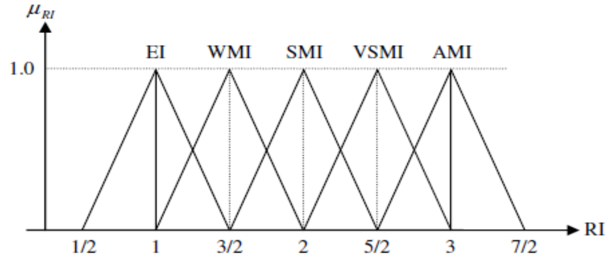

Fig. 6 Linguistic scales for relative importance [35]

TABLE I
LINGUISTIC SCALES FOR IMPORTANCE

Linguistic scale	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Just equal	(1, 1, 1)	(1, 1, 1)
Equally important (EI)	(1/2, 1, 3/2)	(2/3, 1, 2)
Weakly more important (WMI)	(1, 3/2, 2)	(1/2, 2/3, 1)
Strongly more important (SMI)	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Very strongly more important (VSMI)	(2, 5/2, 3)	(1/3, 2/5, 1/2)
Absolutely more important (AMI)	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)

<u>Design the questionnaire for the pairwise comparison:</u> This step will impute the local weights of the criteria for the second level of the ANP model. By using the scale given in Table I, the pairwise comparisons will be carried out by decision experts.

The questions are formulated in terms of dominance or influence: given a parent element, which of two elements being compared with respect to it has greater influence (is more dominant) with respect to that parent element? or, which is influenced more with respect to that parent element? [26]. For instance, in comparing criterion A to criterion B, one asks "How important is criterion A when it is compared with criterion B?". If participant answers "Weakly more important (WMI)", the linguistic scale will be placed in the relevant cell against the triangular fuzzy numbers (1, 3/2, 2). Similarly, all the fuzzy evaluation matrices can be calculated. Pairwise comparison matrices are analyzed by the Chang's extend analysis method and local weights are determined. This step is applied in same manner to calculate the local weights of the sub-criteria (barriers).

- *<u>Step 4:</u>* Determine inner-dependence weights: This step is to determine the inner dependence matrix of each criterion (aspect) with respect to the other criterion with fuzzy scale in Table I. This inner dependence matrix is imputed with the local weights of the criteria, determined in step 3, to compute the interdependent weights of the criteria by using the pairwise comparisons.

For instance, the question based on the dependent aspect (criterion) in the second level in Fig. 5. ''What is the relative importance of aspect A when compared with aspect B on controlling aspect C. By using the imputed relative importance weights, the dependence matrix of the aspects of barriers is formed.

Interdependent weights of the criteria (aspects) are computed by multiplying the dependence matrix of the criteria with the local weights of the criteria as:

$$\begin{bmatrix} 1 & w_{12} & w_{13} & w_{14} \\ w_{21} & 1 & w_{23} & w_{24} \\ w_{31} & w_{32} & 1 & w_{34} \\ w_{41} & w_{42} & w_{43} & 1 \end{bmatrix} \otimes \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ w_4 \end{bmatrix} = \begin{bmatrix} w'_1 \\ w'_2 \\ w'_3 \\ w'_4 \end{bmatrix} \quad (14)$$

Followed by the normalization, the interdependent weights of the criteria are obtained as the following:

$$IDW = (w_1, w_2, w_3, w_4)^T \quad (15)$$

- *<u>Step 5:</u>* Calculate the global weights: This step is to calculate the global weights for the barriers. Global weights for the barriers are calculated by using the interdependent weights of the aspects (criteria) in step 4 and local weights barriers (sub-criteria) in step 3. It is performed by multiplying local weight of the barrier with the inter-dependent weights of the aspect to which it belongs.

The global weights are calculated by the formulation as:

$$GW = LW \ x \ IDW \quad (16)$$

In which *GW* is the global weight of each barrier, *LW* is the local weight of each barrier, and *IDW* is the inner-interdependent weights of the aspect (of barrier).

- *<u>Step 6:</u>* Develop managerial actions for removing barriers: In this step, based on the global weights for each aspect of barriers and barriers, they are prioritized based on their relative importance established in step 5 that helps to the managers for taking the decision to remove them in order to enhance the successful KS in organizations. The barriers have more impact on the KS, which requires serious attention by the managers.

VI. APPLICATIONS OF THE FANP

The fuzzy ANP has been widely applied in various areas by several academics as shown in Table II.

VII. THE RATIONALE FOR THE USE OF THE FANP

The Fuzzy ANP is aptly suited for establishing the relative importance of KS barriers and to find out the interrelationships and inter-dependence among these barriers. Based on the model developed in the ANP approach, action plans can be developed to remove these factors and to help organizations to achieve success of knowledge management.

There are many fundamental reasons in support of the FANP. First, according to Kaur and Mahanti, the use of fuzzy set makes FANP a better selection without taking too much performance time [15]. Additionally, the fuzzy logic deals with the ambiguities affiliated with the preferences of decision makers in the best possible manner [31]. Second, Asan et al. believe that the use of qualitative evaluation criteria, a typical case in expert decision making, may result in decision makers translating the same information in various ways [30]. In summary, Mikhailov and Singh revealed that the main advantages of the FANP compared to the AHP are [34]:

- Can better model the ambiguity and imprecision associated with the pairwise comparison process;
- Successfully derives priorities from inconsistent and consistent judgments successfully;
- Cognitively less demanding for the decision-makers; and
- Can be an adequate reflection of the degree of confidence of and attitude towards risk in the subjective assessments.

TABLE II
A REVIEW OF APPLICATIONS OF THE FANP.

Contributions	Related Literature
The authors first proposed a fuzzy extension of the ANP which uses uncertain individual preferences as input information in the decision-making process. The study applied this approach to the development of decision support systems.	[34]
The study applied the FANP to prioritise design requirements through taking into account the degree of their interdependence with the customer's needs. The authors used the triangular fuzzy numbers in order to enhance the quality of the responsiveness to the design requirements and user's needs.	[39]
The author applied the FANP model to identify faulty behaviour risk, a complex structure, in work system. The FANP was used to address to the difficulties and limitations in measuring the faulty behaviour factors that helps managers to make better decisions in calculating the faulty behaviour risk before it occurs. The study suggested that although the use of the model proposed is specific to a facility, it can also be adapted so that it could be used in other organisations.	[23]
In 2011, Vinodh et al. applied the FANP for supplier selection process. The research was carried out in an Indian electronics switches manufacturing company. The best supplier was determined based on supplier election weighted index. The results of the study indicated that the application of FANP is feasible and adaptable in the modern industrial field.	[22]

VIII. EXPECTED OUTCOMES

By conducting research on using the FANP to impute the relative importance of KS barriers in order to find ways to remove barriers, the expected outcomes as follows:

- A FANP model showing the inter-outer dependences among barriers which are impediments to KS.
- By using pairwise comparison matrices, the relative importance of barriers can be measured. In the other words, the barriers can be prioritized by their importance.
- Derive managerial actions for removing barriers based on the priority of barriers and the interrelationships in the FANP model.
- By developing enablers for KS, managers can examine the interrelationships between enablers and barriers that help to determine how much each enabler affects each barrier.

IX. CONCLUSION AND FUTURE WORK

This paper described the way to apply the FANP to impute the relative importance of KS barriers to help managers to find ways to remove them in order to improve KS. It shows how the FANP can be used to develop the model and prioritize KS barriers which have the interrelations and inter-outer dependences.

We find that although there has been a large amount of literature on identifying and prioritizing KS barriers in order to overcome them, there is a lack of methods that can analyze KS barriers in dynamic and complex environments. Hence, there is great scope for conducting additional research on this issue using FANP.

Our goal in the future is to collect data in order to apply the model proposed in this study and to establish the relative importance of KS barriers. Then, the interrelationships between enablers and barriers can be examined in order to find ways to remove these barriers.

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