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Identifying and ranking knowledge management tools and techniques affecting organisational information security improvement

Mahdi Eslamkhah[a] and Seyed Amin Hosseini Seno[b]

[a]Department of Management, Faculty of Economics and Administrative Sciences, Ferdowsi University of Mashhad, Mashhad, Iran; [b]Department of Computer Engineering, Ferdowsi University of Mashhad, Mashhad, Iran

ABSTRACT

Information system security is one of the most important challenges of today's organisations. Although most organisations use security technologies, they have come to the conclusion that technology alone is not enough. In this study, we analysed and ranked the opinions of IT experts, managers, and Ph.D. students concerning the role of knowledge management in creating, recording, sharing, and applying information security knowledge. First, we identified 62 knowledge management techniques and tools. Then, 20 techniques and tools were investigated in knowledge management cycle using fuzzy screening through interviews and questionnaires. Finally, the network analysis methods, DEMATEL, and VIKOR were employed for weighting, internal relationships, and ranking each of the tools in the evaluation cycle. According to the results, " Knowledge Base" was the most important factor in creating and recording knowledge. In sharing and diffusing knowledge, " Categorisation of Knowledge "scored the top, while "Knowledge Maps" were the most important tool in knowledge application.

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1. Introduction

Today is the era of rapid change and development of knowledge. In order to survive, organisations must constantly collect proper data from internal and external environments and convert them into knowledge. In such circumstances, knowledge that is considered to be a strategic and valuable asset has taken the place of energy and capital. It has also become vital for survival of dynamic and innovative organisations. Knowledge is considered to be the secret to success of organisations in global competition. Knowledge management is one of the tools which can help organisations to achieve their goals (Nikoukar, Soltani, & Pashai, 2014). The term "information security" means the protection of data and related systems from unauthorised access, use, disclosure, disturbance, modification, or destruction in order to provide (i) integrity (i.e., protection against inappropriate information modification or destruction ensuring that information is not denied); (ii) confidentiality(i.e., maintaining permissible access and disclosure limits, including privacy and personal information protection devices); (iii) availability (which means ensuring timely and reliable access and use of information) (Cebula & Young, 2010).

Therefore, information system security is one of the most important challenges of today's organisations. Although most organisations use security technologies, they have come to the conclusion that technology alone is not enough. The main threat for organisational security is rooted in employees who do not have adequate knowledge of organisational security. Therefore, promoting knowledge management security of the users has seriously interested organisations (ESFANDYAR Pour, & Akbari, 2016). The knowledge of users is one of the most important factors in information security management and nearly 70% of security incidents occur due to lack of knowledge. New security threats are created as a result of rapid changes in IT and its application. Smart and new methods have been proposed by researchers to reduce the risks of security threats. In addition to using these processes, organisations use firewalls, proxies, antiviruses, intrusion detection systems, digital signature, protocols, and certain other network tools. Yet, security is beyond sole reliance on technical solutions. Other factors such as HR, policies, procedures, processes, and standards must be taken into account. In general, information security management consists of processes and procedures which employees use for maintaining confidentiality, availability, and integrity of data and valuable assets (Mittal, Roy, & Saxena, 2010). Knowledge management helps the survival of organisations and provides competitive advantage by identifying assets, experts, and effective management of resources. When employees leave an organisation, recording their knowledge and activities throughout the years of their work experience is important for that organisation. Provision and maintenance of information security is

CONTACT Seyed Amin Hosseini Seno hosseini@um.ac.ir Department of Computer Engineering, Head of Virtual Learning Center, Ferdowsi University of Mashhad, Iran

one of the challenges in KM. KM covers a wide range of technologies including data mining, multimedia, participatory systems, and the web. Accordingly, multimedia systems and participatory systems help knowledge management activities in web data management so that the assets of organisations need to be maintained and rivals must not have access to each other's secrets in commercial activities(Bertino, Khan, Sandhu, & Thuraisingham, 2006). The cyberattack to The Ministry of Petroleum of Iran in April 2012 imposed multiple harms and costs to the affiliated companies. Since then, the National Iranian Oil Products Distribution Company has paid exorbitant costs in order to implement in formation security management and purchase the necessary security equipment. If human factor and the promotion of information security knowledge are ignored in security policies and technical tools, loss of investment and irreversible damages would occur (ESFANDYAR Pour, & Akbari, 2016). Studies show that lack of knowledge is the main cause of penetration of network security. Malicious hackers sometimes try to get information by introducing themselves as authorised members. They use social engineering methods and deceive employees for passwords. Final users and information system experts can be the source of error in information systems, lack of knowledge, entry of incorrect data, and not observing systems security during new software development bring about security problems in organisations (Laudon & Laudon, 2012). Considering the importance of the topic, this paper aim to analyse and rank the factors that affect the promotion of information security knowledge. Therefore, the key question addressed in this study is as follows: What are the main roles of effective factors of knowledge management in promoting knowledge security of users in organisations in knowledge creation and recording, sharing and diffusion, and application and acquisition. We also ranked the internal relationships of each KM tool. To this end, Analytic Network Process, Decision Making Trial and Evaluation, and VIKOR were employed.

2. Literature review

Uriarte (2008) defined knowledge as interpreted information, principles, models, and visions obtained by man. He considered the following three aspects: result orientation, technology orientation, and process orientation (Uriarte, 2008). Massingham (2014) defined knowledge management according to resources, currents, and enablers and considered the process-centric view against the output view (Massingham, 2014). Employees who use organisational knowledge can protect themselves against organisational theft and disseminate organisational information. Subsequently, investment in information protection has grown, and organisations have spent a lot of resources on this and knowledge is considered as an organisational asset. The literature review clearly indicates that successful knowledge protection significantly improves organisational performance upgrade. However, managers at different levels pay little attention to information security issues in their businesses (Manhart & Thalmann, 2015). Undoubtedly, knowledge management is considered a vital activity in all organisations and a key factor to ensure success and competitive advantage. Thus, information is claimed to be an asset and is considered to be essential for businesses. Information can be shaped or transferred in different forms. The interaction between private and public networks and sharing information make its control more difficult.

Most information systems have not been safely designed. Security in organisations depends on technical tools, plus security procedures and policies. All employees play a vital role in knowledge security and are considered the cornerstone of human resources information security (Said, Abdullah, Uli, & Mohamed, 2014). Although organisations need to empower employees to access information electronically in order to carry out activities successfully, the employees themselves must always be learning. Doing this and using electronic tools creates a lot of information security risks. The main issue surrounding information technology and use of learning tools is not merely hardware and technical discussions, but the main factors are human resources (Russ, Lytras, & Maier, 2008). KM is an essential process for generating, collecting, processing, and transferring knowledge to obtain competitive advantage. Since knowledge is considered to be a vital component, organisations gain limited benefit from isolated knowledge of individuals or working groups. In order to fully benefit from the real value of knowledge, it must be collected and transferred within organisations (Khani, & Nadi, 2011; Uriarte, 2008). Knowledge and its establishment are valuable sources of business opportunities and competitive advantage for most current organisations. Although knowledge establishment, diffusion, and KM have been widely studied, the issue of knowledge security has received less attention in the literature. Given the security of knowledge and risk analysis, most of the available methods are in the analysis and risk analysis framework. This framework presents a general technical view of information and technologic assets. Knowledge security is considered to be the knowledge of interactions and thinking of individuals and a source of risk to the security of knowledge (Ilvonen, Jussila, & Kärkkäinen, 2015). Information is one of the most prominent assets of organisations, and it should be protected from security breaches (Joshi & Singh, 2017). All people who are somehow associated with information security of an organisation must be able to manage security risks (Bodin, Gordon, & Loeb, 2008). Organisations of any size in the public and private sectors are progressively depending on information and technology resources that are supported by people and facilities in order to succeed in

executing business processes. The failure of these assets has a direct negative influence on business processes. Given these relationships, risk management of these assets is one of the important factors in organisational achievement .Thus cybersecurity Operations Risks are defined as operational risks for information and technologic assets that affect the confidentiality, availability, and integrity of information or information systems (Cebula & Young, 2010). IT operational risk is considered to be a threat to the integrity, confidentiality, and availability of IT data or assets (Benaroch, Chernobai, & Goldstein, 2012). Given the current trend of information transfer in the borderless and vulnerable world, information security has become a controversial topic. This raises further concerns regarding the use of information security risk management for effective and economic control strategies. Organisations have quickly realised that information security is an important aspect of business strategy. The concern of vigilant organisations includes using information security risk management to identify security risks and providing risk profiles (Shamala, Ahmad, Zolait, & Sedek, 2017). Cebula and Young (2010) attempted to recognise and organise sources of operational cyber security risks into four categories: the actions of people, systems and failures of technology, internal process failures, and external events (Cebula & Young, 2010). The major challenge in today's world is how to manage operational risk in a business environment that is known to have permanent fluctuations. Operational risks include foreign fraud, internal fraud, health of the work environment and work activities, customers, products and business activities, natural disasters and damage to physical assets, and failure of infrastructure and technologies. The operational risks include the following types: failure in information and communication technologies and natural disasters, manpower mistakes, failure in processes, and expected losses due to operational risk incidents (Martínez-Sánchez, Martínez-Palacios, & Venegas-Martínez, 2016). Jouini, Rabai, and Aissa (2014) divided security risks of information systems into two categories: internal (environmental threats, technological threats, manpower) and external (environmental threats, technological threats, human resources) (Jouini et al., 2014). Comm Ja'nel Esterhuysen (2003) stated four levels at which an operational risk can appear including people, processes, technical, and technological (B. Comm Ja'nel Esterhuysen, 2003). In the cybersecurity environment, risk management focuses on the risks inherent in people and technology interventions. Operational risks are also defined as risks that are increased due to actions of individuals, failure of systems and equipment, internal processes, and external events (Cebula & Young, 2010).The literature published on the risk of IT operations is limited. The gap in the literature in this area is more evident than that of empirical work on the economic impacts of operational IT risks. In this process, all studies utilise the event study methodology, except for Ko and Dorantes (2006) who use a matched sample comparative analysis research design. Empirical studies of IT and operational risk events are presented in Table 1 (Benaroch et al., 2012). To solve the problem of information security, organisations need to apply a wide range of knowledge, technology, and organisational rules. Yet, we must make sure not to focus on technical solutions but other key factors of information security including processes and employees (Taj Far, Mahmudi, Soltani, & Soltani, 2014). Despite the previously proposed technical solutions for solving the security of organisations, information security management has still remained a constant challenge in organisations. With the emergence of new technologies in information security, new challenges and threats have come up, showing that technical solutions alone cannot solve the security problems of organisations. The ever-increasing reliance of businesses on information and assets has created a severe need for security. With rapidly technological advances, today's era has created new threats for businesses and information assets at various stages of the information cycle (creation, processing, storage, and diffusion) (Singh, Gupta, & Ojha, 2014). The growing complexity of business environments and internal activities of companies have doubled the importance of knowledge as a vital source. Knowledge management consists of three key activities: creation, coding, and

Table 1. Empirical studies of information technology operational risk events.

Focus of risk events	Study
Internet security breaches	Cavusoglu et al. (2004)
Mainly security breaches	Wang (2009)
Information breaches involving theft or loss of consumer or member data	Tanimura and Wehrly (2009)
Failures of operational information technology systems that are "data"-and "function"-related	Goldstein et al. (2011)
Mainly security breaches	Campbell et al. (2003)
Security breaches	Garg et al.(2003)
Virus attacks	Hovav and D'Arcy (2004)
Mostly website outages(due to DOS attacks)	Hovav and D'Arcy (2003)
Mostly security incidents exposing private information	Acquisti et al. (2006)
Site and email out ages due to external and internal technical reasons	Anthony et al. (2006)
Information breaches	Ko and Dorantes (2006)
Security breaches	Kannan et al. (2007)
Phishing incidents	Leung and Bose (2008)
"Internet" security breaches	Bolster et al. (2010)
Mainly data breaches	Gatzlaff and McCullough (2010)

Sources: Benaroch et al. (2012).

Table 2. Tools and techniques in knowledge management cycle.

Author	Tools and techniques
Uriarte (2008)	Document management systems, company portals, knowledge maps and skill management, data bases, groupware, work flow management, associations and communities
Asian Productivity Organization (APO) (2010)	**Non IT-based tools and methods**: Learning and idea submission systems, brainstorming, help of colleagues, storytelling, revisions after act, physical team work places, knowledge management assessment tool of Asian Productivity Organization, associations, knowledge cafes, knowledge ranking. **IT-based tools and methods**: Document management system, advanced search tool, knowledge maps, trainer, knowledge clusters, head hunter, knowledge management maturity model, knowledge portal, data bases, internet telephone, knowledge clusters, social media services, weblogs, competence programmes of knowledgeable workers, vide sharing, virtual team work places
Kimiz (2005)	Content development, content management, participation and communication, network technology, e-learning, artificial intelligence technologies
Liao (2003)	Knowledge-based systems, data mining, it technologies, expertise systems, data bases, modelling tools
Panahi, Watson, and Partridge (2013)	Wiki, weblogs, micro-weblogs, social networks, multimedia sharing tools, RSS

Sources: Asian Productivity Organization (APO, 2010), Uriarte (2008), DALKIR Kimiz (2005), SHU-HSIEN Liao (2003), Panahi et al. (2013), Massingham (2014).

Table 3. Classification of knowledge management processes by experts.

Author	Knowledge management cycle
Hedlund	Knowledge acquisition, storage, application, and maintenance
Dejarnet	Knowledge construction, imagination, diffusion, and application; knowledge maintenance and purification
Quintas	Process or method of knowledge creation, collection, occupation, sharing, and application
Demerset	Knowledge construction, diffusion, and imagination
Lettieri	Knowledge management in non-profits organisations including knowledge acquisition, coding, storage, recovery, diffusion, application, and creation
Solingen	Knowledge collection, establishment, diffusion, development, and application
ROLLET	Knowledge planning, creation, integration, organisation, transfer, maintenance, and assessment
Asian Productivity Organisation	Identification, creation, storage, sharing, diffusion, and application
Dalkir and Kimiz	Knowledge creation and recording, sharing, diffusion, application, and acquisition

Sources: Asian Productivity Organization (APO) (2010), DALKIR Kimiz (2005), Rollet (2003), Nikoukar et al. (2014).

transfer of knowledge. It has a vital role in empowering organisations to increase productivity and individual and team activities. Thus, KM can play a key role in increasing power and facilitating KM tools including the activities which promote transfer, creation, coding, and application of knowledge. KM tools and technologies can be used in line with communication goals, participation, e-learning, commercial intelligence, and content development (Rollet, 2003; Ruggles, 1997). Knowledge management processes and techniques are the subject of debate among researchers. Tables 2 and 3 show the tools and techniques in knowledge management cycle and classification of knowledge management processes by experts.

3. Methodology

This study is based on the combined method using the multi-criteria approach. First, the tools that are effective in promoting knowledge security were determined in the knowledge management cycle using literature review and opinions of experts. Then, the set of tools were filtered using fuzzy screening. Finally, DEMATEL was employed to determine the relationship among the tools. ANP was used to weight the tools. Finally, VIKOR was used to rank the tools in different stages (creation and recording, diffusion and sharing, acquisition and application). Figure 1 shows the framework. The questionnaires were validated, as data collection tools. The items were validated by the opinions of experts. Experts for Fuzzy Screening were IT experts and philosophers in the Computer Science, Economics and Administrative Sciences, Education departments at the Ferdowsi University of Mashhad, Iran such as Dr. Mohsen Kahani, Dr. Mohammad Lagzian, Dr. Mojtaba Kafashan Kakhaki, etc.. Respondents to the Fuzzy Screening, DEMATEL, and ANP questionnaires were IT experts, philosophers, and Ph.D. students. DEMATEL, ANP, and VIKOR were employed to analyse the data using SPSS, MATLAB, and Super Decision. We used SPSS to summarise the characteristics of the respondents to the questionnaires (Fuzzy Screening, DEMATEL, and ANP(, write the total-influence matrix $\boldsymbol{T}$ in Equation 17 in MP-files in MATLAB, implement the ANP steps in Supper Decision, and draw the graphs in DEMATEL by using Visio.

4. Data analysis

4.1. Fuzzy screening process

Fuzzy screening is a two-stage process which consists of three components. The first component is a set of decision-making options. We tend to select a subset for further investigation.

$$A = \{A_1, A_2, \ldots, A_m\} \tag{1}$$

The second component is a set of criteria by which assessment is done.

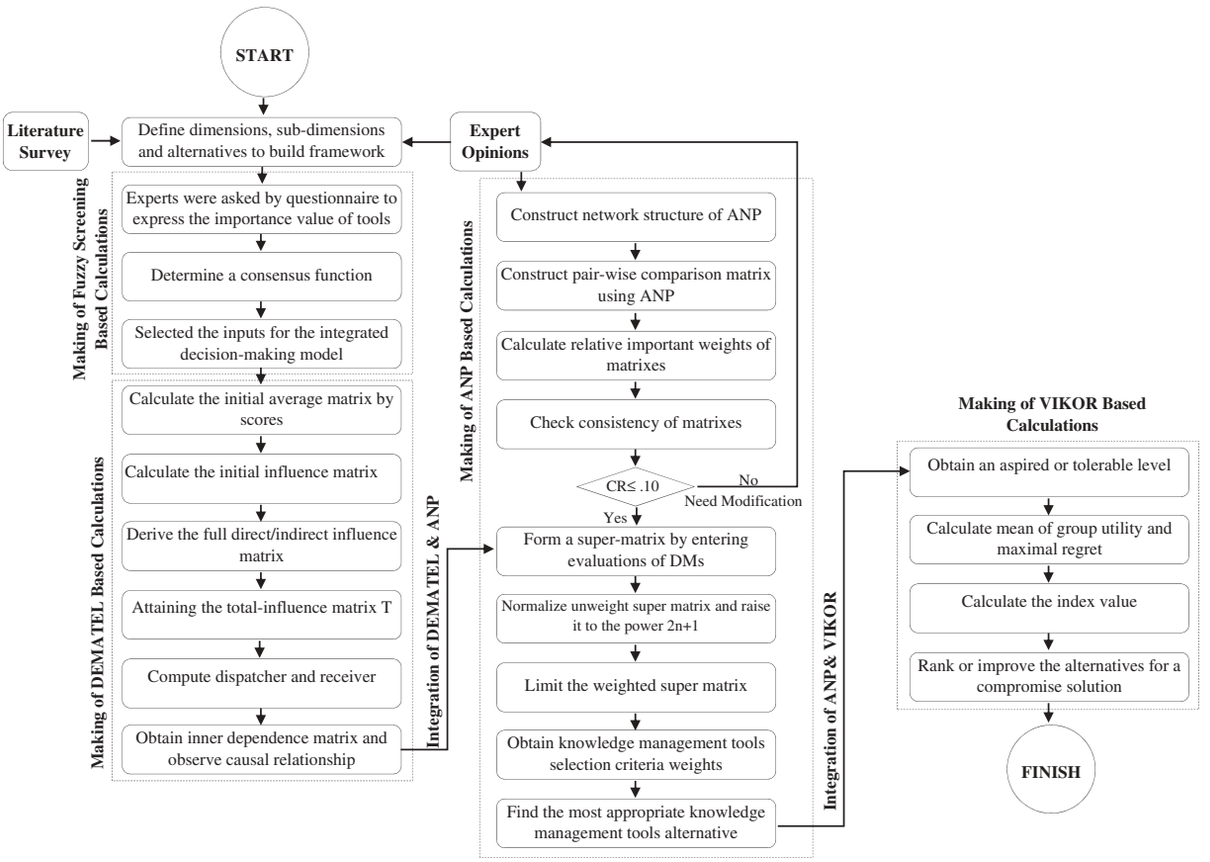

Figure 1. A general view of selection and evaluation framework of knowledge management tools.

$$C = \{C_1, C_2, \ldots, C_n\} \tag{2}$$

The third component is a group of experts (panel). Their opinions are used for screening.

$$E = \{E_1, E_2, \ldots, E_r\} \tag{3}$$

Each expert must state to what extent he/she is convinced by various criteria. This assessment is done according to the comparison, shown in Table 4 (S).

Using such a scale provides a natural order of S_i, so that for any $i < j$: $S_i < S_j$ the maximum and minimum number of any element are determined as follows:

$$Max\left(S_i, S_j\right) = S_i \qquad S_i \geq S_j \tag{4}$$

$$Min\left(S_i, S_j\right) = S_j \qquad S_i \geq S_j \tag{5}$$

Each expert provides a set of n value (the number of criteria) for each alternate on the basis of the above scale. These values show the satiate degree of the given alternative in the relationship for the j^{th} criteria.

$$\{\pi_1, \pi_2, \ldots., \pi_n\} \tag{6}$$

Table 4. Seven-part fuzzy spectrum for weighting.

Very low (WB)	S_1	Medium (N)	S_4	Very high (WK)	S_7
Low (B)	S_2	Fairly high (PK)	S_5		
Fairly medium (PN)	S_3	High (K)	S_6		

Source: Azar & Faraji, 2010)

The next step in this process is the single evaluation of each alternative by every alternative. Thus, the value of the negative must be determined as follows:

$$Neg(S_i) = S_{q-i+1} \tag{7}$$

Then, the single score of the alternatives are calculated by each expert (U) as follows:

$$Min\left\{Neg\left(I_{kj}\right) \vee \pi_{ijk}\right\} \quad i = 1, 2, \ldots, m \qquad j = 1, 2, \ldots, n \qquad k = 1, 2, \ldots, r \tag{8}$$

where U_{ik} is the single score of the i^{th} alternative of k expert relation, I_{kj} is the importance degree of j^{th} criteria by the k^{th} expert, and $\pi_{ikj}$is the satiate possibility of the j^{th} criteria by the i^{th} alternative in the opinion of the k^{th} expert. The result of the screening process in the first step is experts' single scores on different alternatives.

$$\{U_{ik}\} = \{U_{i1}, U_{i2}, \ldots., U_{ir}\} \tag{9}$$

In the second step of the screening process, we pay attention to the structure of assessments that are done by experts in order to perform the overall assessment of each alternative. The first step in this stage is determination of a consensus function (Q) for the decision-making body. The function states how many experts are required to accept an option and the option passes the screening process. Accordingly,

for each i (k = 1, 2,. . .,r), experts provide a value decision-making body $Q(k)$. $Q(k)$ states that if k number of experts are satisfied with an option, then it states the method acceptable. Now, if q indicates the number of points in the selected scale and r indicates the number of experts participating in the decision-making process, then the consensus function is defined as shown in Equation(10).

$$\begin{aligned} &Q_A(k) = S_{b(k)} \\ &B(k) = Int\left[1 + \left(k\,\tfrac{q-1}{r}\right)\right] \quad , \; k = 1,\, 2,\, \ldots, r \end{aligned} \tag{10}$$

where *Int* implies integer and it is clearly meant for every value of e and q in Equation 11 and Equation12, The following equations are correct.

$$Q_A(0) = S_1 \tag{11}$$

$$Q_A(r) = S_q \tag{12}$$

After selecting the proper consensus function, we can use the Ordered weighted averaging operator for expert's consensus. Here, for each of m alternatives, a single score is produced by the k^{th} (k = 1,2,. . .,r) expert. Now, for each of the alternatives, the expert's single assessment must be arranged in descending format. B_{ij} states the j^{th} highest approach i for which we can calculate total assessment of approach i:

$$U_i = \max_j\{Q(j)\} \wedge B_{ij} \quad , i = 1, 2, \ldots, m \tag{13}$$

where,

- B_{ij}: the value of the j^{th} good approach
- $Q(i)$: the value of decision-maker sense that needs the minimum support of the j expert
- $Q(j) \wedge B_{ij}$: the weighting j^{th} good score alternative i (B_{ij}) on the basis of decision-maker willingness ($Q(i)$).

The Max operator plays the summation role in the normal averaging way.

On the descriptions that were mentioned, equation U_{i} can spot the generalisation of average normal weight.

4.2. MCDM methods

According to the literature, the AHP and ANP have been successfully utilised in numerous studies. AHP is an appropriate method for applying with various methods to calculate the weight of each index and finally compare the alternatives. Although AHP seems to be suitable, ANP is more powerful in this area. ANP can consider relations of all indices together, and for this ability, it seems to be more powerful than AHP. However many methods may be applied for comparison between alternatives such as TOPSIS and VIKOR. According to Saaty (2003) when many decisions cannot be structured hierarchically due to interaction and dependence of indices, ANP can solve the problem and examine the relative weights of performance indices and consequently give more realistic answers to the needs. TOPSIS and VIKOR are the most popular MCDM methods. These methods are very suitable for comparison of alternatives and helping to choose the best option among different alternatives based on the multiplicity of criteria (Dalalah, Hayajneh, and Batieha (2011)). Evaluating indices and criteria in these methods can be done in two ways. In the first way, weights can be calculated in group decision-making with experts and another way is using the AHP and ANP techniques for calculating the weights. According to the literature, both TOPSIS and VIKOR may be applied for competing problem among the evaluation criteria and ranking them. However, TOPSIS is not appropriate for ranking, and it is useful for improving the gaps among the criteria. DEMATEL is a powerful technique for using in various areas. DEMATEL has been used in three ways to increase the validity of research as shown in the literature review. DEMATEL has been applied to identify the importance of perspectives with cause-and-effect relationships among them. Moreover, DEMATEL has been used to identify important indices among perspectives. Notably, Safaei Ghadikolaei, Chen, Hashemkhani Zolfani, and Akbarzadeh (2011) used DEMATEL to recognise the important index in each measures. Application of DEMATEL is not for ranking the criteria, but it is useful for considering the cause-and-effect relations of criteria and results in order to select and identify important criteria. In future research studies, it would be very useful to compare the results of using the DEMATEL method with those of the AHP or ANP methods. Table 5, Table 6 show the comparison of results among MCDM methods and the Studies that combine DEMATEL, ANP, and VIKOR .

As any measure may be inter-influenced, this study adopts the DEMATEL method to perceive the influenced structure between the criteria and know the problems areas that may be improved. After finding the impact structure between each measure, we weighted them by combing with the analytic network process technique to know the most important measure that will support create the knowledge management tools value. In order to comprehend the weakness of each measure and rank the first important strategy to be carried out, the VIKOR method will be utilised for calculating compromise ranking and gap of the alternatives. In brief, the structure of assessment contains three main steps: (1) creating the impact relations map across the criteria by the DEMATEL method, (2) computing the weights of each measure by combining the analytic network

Table 5. Comparison's results among MCDM methods (Hashemkhani Zolfani & Radfar, 2011).

Methods	Select	Reason
AHP and ANP	ANP	ANP can consider relations of all indices with together and for this ability seems is more powerful than AHP
TOPSIS and VIKOR	VIKOR	Both apply the concept of compromise to solve the competing problem among the evaluation criteria and then rank the order of alternatives. However, the TOPSIS method is used to provide information on how to improve the gaps among the criteria so as to achieve the desired/aspired level and cannot be used for ranking purpose due to its blind point proven by Opricovic and Tzeng (2004)
DEMATEL	–	1. Apply for identify importance of perspectives with cause-and-effect relationship among them 2. Use for identifying important indices among perspectives 3. Use for identifying the important index in each criterion

Table 6. Studies that combine DEMATEL, ANP, and VIKOR. (Büyükö`kan & Güleryüz, 2016).

Authors	Research scopes	Year
Liou and Chuang	Outsourcing provider selection	2010
Ho et al.	Portfolio selection	2011
Hsu et al.	Selection of best vendor in recycle industry	2012
Liu et al.	Implementation of o tourism policy management	2012
Wang and Tzeng	Brand marketing	2012
Chiu et al.	Improving e-store businesses in order to satisfy customer needs	2013
Lee and Lee	Evaluation of hospital service quality	2013
Lee	Merger and acquisition evaluation of Taiwanese banks	2013
Lu et al.	Evaluation and improvement of Radio-frequency identification adoption in Taiwan's health care industry	2013
Peng and Tzeng	Improving tourism destination competitiveness and supplier evaluation and improvement	2013
Yang et al	Assessment of security risk control for IT managers	2013
Zolfani and Ghadikolaei	Performance evaluation of private universities	2013
Chen	Exploring key factors for procurement circulation	2014
Hu et al.	Improving smart phone in order to satisfy customer needs	2014
Lee	Location selection of real estate brokerage services DEMATEL	2014
Liu et al.	Material selection	2014
Wang et al.	Six sigma project selection	2014
Kuo et al.	Supplier selection	2015
Lin	Determining product position	2015
Lu et al.	Exploring mobile banking services for user behaviour	2015
Lu et al.	Mobile commerce	2015
Shen and Tzeng	Financial performance improvement of the banking industry	2015
Huang et al.	Company's core competitiveness improvement	2016

process based on the impact relations map, and (3) ranking or enhancing the priorities of alternatives of brand marketing through the VIKOR technique.

However, there are many complicated and interrelated factors in information security and knowledge management. One of the hybrid MCDM model that combines the DEMATEL technique with the analytic network process and VIKOR techniques can be successfully utilised to answer the complicated structure of causal relationships. Finally, you possibly can probe the interconnected relationships between the dimensions and criteria and so build an IRM among the factors for assessment. The weights of each factor are obtained to select the best KM tools using the DEMATEL combination and analytic network process (Li & Tzeng, 2009a, 2009b; Tzeng, Chiang, & Li, 2007). We then recognise the most appropriate strategy by VIKOR and present and test a decision model as a reference for companies (Chen & Tzeng, 2011; Chen, Hsu, & Tzeng, 2011; Chen et al., 2011; Huang, Tzeng, & Ho, 2011; Hung, Chou, & Tzeng, 2011; Liou, Tzeng, Tsai, & Hsu, 2011; Liu, Tzeng, & Lee, 2013; Ou Yang, Shieh, Leu, & Tzeng, 2009; Shen, Lin, & Tzeng, 2011; Yang & Tzeng., 2011).

4.3. Building a hybrid MCDM model combining DEMATEL with analytic network process

4.3.1. The DEMATEL for building IRM

DEMATEL has been effectively used in numerous circumstances, such as marketing strategies, e-learning assessment, control systems and safety problems (Chiu, Chen, Tzeng, & Shyu, 2015; Wang & Tzeng, 2012), information security(Ou Yang et al., 2009), financial stock investment (Lee, Tzeng, Guan, Chien, & Huang, 2009), water resources, and the environment (Chen, Lien, & Tzeng, 2010). The methodology can examine interdependence among variables and limit the relations that reflect the characteristics within a systemic and developmental trend. The steps in this method are described (Li & Tzeng, 2009a, 2009b; Liou, Tzeng, & Chang, 2007):

S.1: *Direct matrix formation*. Respondents are asked to identify and define the relations between these elements, as shown by a_{ij}, Using the integer scale, it has zero to four variables. From any cluster of direct matrices, it is possible to derive an matrix M by experts in which each element is the average of the corresponding elements in the matrix M.

S.2: *Normalise direct matrix*. The initial influence matrix $N = [n_{ij}]_{n\times n}$ is acquired by normalising the matrix $\boldsymbol{M}$ (indicated by degree, i.e., indicated by membership and $0 \le n_{ij} < 1$, also called the "fuzzy cognitive matrix"), in which all principal diagonal elements equal zero. Based on $\boldsymbol{N}$, the initial effect that an element exerts and receives from another is indicated. The map depicts contextual relationship among the elements of a system, in which the numeral represents the degree of influence .

S.3: computing *The full direct/indirect influence matrix.* continuous decrease of the indirect effects of problems along the powers of N, e.g., $\boldsymbol{N^2}$,$\boldsymbol{N^3}$, …, $\boldsymbol{N^m}$ and $\lim_{l\to\infty} N^l = [0]_{n\times n}$where $N = [n_{ij}]_{n\times n}$, $0 \le n_{ij} < 1$ and $0 \le \sum_i n_{ij} \le 1$ or $0 \le \sum_j n_{ij} \le 1$ and at least one column or one row of summation equals one, but not all. Let the (i,j) element of matrix $\boldsymbol{M}$ be denoted by a_{ij}, the matrix $\boldsymbol{N}$ be as follows:

$$N = s \times M \tag{14}$$

where

$$s = Minimum\left[\frac{1}{\max imum_{\,1\le i\le n}\sum_{j=1}^{n}|a_{ij}|}, \frac{1}{\max imum_{\,1\le i\le n}\sum_{i=1}^{n}|a_{ij}|}\right] \tag{15}$$

And

$$\lim_{l\to\infty} N^l = [0]_{n\times n}, \quad 0 \le n_{ij} \le 1 \tag{16}$$

S.4: Acquire *the total-influence matrix* $\boldsymbol{K}$. The matrix $\boldsymbol{K}$ can be acquired by using Equation (17) where $\boldsymbol{I}$ is denoted as the recognise matrix.

$$k = N + N^2 + \ldots + N^l = N(I-N)^{-1} \quad when\, l \to \infty \tag{17}$$

If we calculate vector $\boldsymbol{r}$ and $\boldsymbol{c}$ vectors separately in the matrix $\boldsymbol{K}$ through Equations (18) and (19), then

$$K = [k_{ij}], \quad i,j = 1,2,\ldots,n, \tag{18}$$

$$\begin{aligned} p &= [p_i]_{n\times 1} = \left[\sum_{j=1}^{n} k_{ij}\right]_{n\times 1}, \\ z &= [z_j]_{n\times 1} = \left[\sum_{i=1}^{n} k_{ij}\right]^{/}_{1\times n} \end{aligned} \tag{19}$$

where superscript 0 denotes transposition.

If p_i denotes the row sum of the i^{th} row matrix $\boldsymbol{K}$, then p_i shows the sum of direct and indirect effects of factor i on the other factors/criteria. If z_i denotes the column sum of the j^{th} column of matrix $\boldsymbol{K}$, then z_j indicates the sum of direct and indirect effects that factor j has received from the other criteria. Furthermore, when $j = i$ (i.e. the sum of the row and column aggregates) $(p_i + z_i)$ provides an index of the strength of influences given and received. Thus, $(p_i + z_i)$ indicates the degree that the factor i plays in the problem. If $(p_i - z_i)$ is positive, then factor i is affecting other criteria, and if $(p_i - z_i)$ is negative, then factor i is being affected by other criteria (Tsai & Chou, 2009; Tzeng et al., 2007; Wu & Lee, 2007).

4.3.2. Combining the analytic network process technique for computing weights of criteria based on the impact relations map

We call the matrix $K_c = [k_{ij}]_{n\times n}$acquired by the criteria and $K_D = \left[k_{ij}^D\right]_{m\times m}$ acquired by dimensions from $\boldsymbol{K_c}$. Then, we normalise the supermatrix $\boldsymbol{K_c}$ for the analytic network process weights of dimensions(clusters) by utilising the matrix $\boldsymbol{K_D}$.

S.5: *Create the unweighted Supermatrix*. Each column of the total influence matrix derived from the DEMATEL is normalised.

$$K_c = \begin{bmatrix} K_c^{11} & \Lambda & K_c^{1j} & \Lambda & K_c^{1n} \\ \mathrm{M} & & \mathrm{M} & & \mathrm{M} \\ K_c^{i1} & \Lambda & K_c^{ij} & \Lambda & K_c^{in} \\ & & \mathrm{M} & & \mathrm{M} \\ K_c^{n1} & \Lambda & K_c^{nj} & \Lambda & K_c^{nn} \end{bmatrix} \tag{20}$$

After normalising $\boldsymbol{K_c}$ by dimensions, we will acquire K_c^awhich is shown in Equation (21).

$$K_c^{\alpha} = \begin{bmatrix} K_c^{\alpha 11} & \Lambda & K_c^{\alpha 1j} & \Lambda & K_c^{\alpha 1n} \\ \mathrm{M} & & \mathrm{M} & & \mathrm{M} \\ K_c^{\alpha i1} & \Lambda & K_c^{\alpha ij} & \Lambda & K_c^{\alpha in} \\ & & \mathrm{M} & & \mathrm{M} \\ K_c^{\alpha n1} & \Lambda & K_c^{\alpha nj} & \Lambda & K_c^{\alpha nn} \end{bmatrix} \tag{21}$$

A description for the normalisation of $K_c^{a11}$is indicated as Equations (22) and (23), and other K_c^{ann} are as above.

$$o_{ci}^{11} = \sum_{j=1}^{m_1} k_{ij}^{11}, \quad i = 1, 2, \ldots, m_1, \tag{22}$$

$$K_c^{a11} = \begin{bmatrix} k_{c11}^{11}/o_{c1}^{11} & \Lambda & k_{c1j}^{11}/o_{c1}^{11} & \Lambda & k_{c1m_1}^{11}/o_{c1}^{11} \\ \mathrm{M} & & \mathrm{M} & & \mathrm{M} \\ k_{ci1}^{11}/o_{ci}^{11} & \Lambda & k_{cij}^{11}/o_{ci}^{11} & \Lambda & k_{cim_1}^{11}/o_{ci}^{11} \\ \mathrm{M} & & \mathrm{M} & & \mathrm{M} \\ k_{cm_11}^{11}/o_{cm_1}^{11} & \Lambda & k_{cm_1j}^{11}/o_{cm_1}^{11} & \Lambda & k_{cm_1m_1}^{11}/o_{cm_1}^{11} \end{bmatrix} = \begin{bmatrix} k_{c11}^{a11} & \Lambda & k_{c1j}^{a11} & \Lambda & k_{c1m_1}^{a11} \\ \mathrm{M} & & \mathrm{M} & & \mathrm{M} \\ k_{ci1}^{a11} & \Lambda & k_{cij}^{a11} & \Lambda & k_{cim_1}^{a11} \\ \mathrm{M} & & \mathrm{M} & & \mathrm{M} \\ k_{cm_11}^{a11} & \Lambda & k_{cm_1j}^{a11} & \Lambda & k_{cm_1m_1}^{a11} \end{bmatrix} \tag{23}$$

Let the total-influence matrix match and fill the interdependence dimensions. It is called U and is indicated in Equation (24) which is based on the transpose of the normalised influence matrix by dimensions, i.e., $\boldsymbol{U} = \left(K_c^a\right)'$.

$$U = \left(K_c^a\right) = \begin{bmatrix} u^{11} & \Lambda & u^{i11} & \Lambda & u^{n1} \\ \mathrm{M} & & \mathrm{M} & & \mathrm{M} \\ u^{1j} & \Lambda & u^{ij} & \Lambda & u^{nj} \\ \mathrm{M} & & \mathrm{M} & & \mathrm{M} \\ u^{1n} & \Lambda & u^{in} & \Lambda & u^{nn} \end{bmatrix} \tag{24}$$

If the matrix $\boldsymbol{u^{11}}$ is blank or zero which is indicated in Equation (25), it means that the matrix between the dimensions or criteria is independent and with no interdependence, and the other $\boldsymbol{U^{nn}}$ are as indicated above.

$$U^{11} = \begin{bmatrix} k_{c11}^{a11} & \Lambda & k_{c1j}^{a11} & \Lambda & k_{cm_11}^{a11} \\ \mathrm{M} & & \mathrm{M} & & \mathrm{M} \\ k_{ci1}^{a11} & \Lambda & k_{cij}^{a11} & \Lambda & k_{cm_1j}^{a11} \\ \mathrm{M} & & \mathrm{M} & & \mathrm{M} \\ k_{c1m_1}^{a11} & \Lambda & k_{cim_1}^{a11} & \Lambda & k_{cm_1m_1}^{a11} \end{bmatrix} \tag{25}$$

S.6: In order to obtain the weighted supermatrix according to Equation (26), each column will sum for normalised.

$$K_D = \begin{bmatrix} k_D^{11} & \Lambda & k_D^{1j} & \Lambda & k_D^{1n} \\ \mathrm{M} & & \mathrm{M} & & \mathrm{M} \\ k_D^{i1} & \Lambda & k_D^{ij} & \Lambda & k_D^{in} \\ \mathrm{M} & & \mathrm{M} & & \mathrm{M} \\ k_{D_1}^{n1} & \Lambda & k_D^{nj} & \Lambda & k_D^{nn} \end{bmatrix} \tag{26}$$

We normalise the matrix $\boldsymbol{K_D}$ and obtain a new matrix K_D^a that is indicated as Equation (27) (where $t_D^{aij} = t_D^{ij}/d_i$).

$$K_D^a = \begin{bmatrix} k_D^{11}/d_1 & \Lambda & k_D^{1j}/d_1 & \Lambda & k_D^{1n}/d_1 \\ \mathrm{M} & & \mathrm{M} & & \mathrm{M} \\ k_D^{i1}/d_i & \Lambda & k_D^{ij}/d_i & \Lambda & k_D^{in}/d_i \\ \mathrm{M} & & \mathrm{M} & & \mathrm{M} \\ k_D^{n1}/d_n & \Lambda & k_D^{nj}/d_n & \Lambda & k_D^{nn}/d_n \end{bmatrix} = \begin{bmatrix} k_D^{a11} & \Lambda & k_D^{a1j} & \Lambda & k_D^{a1n} \\ \mathrm{M} & & \mathrm{M} & & \mathrm{M} \\ k_D^{ai1} & \Lambda & k_D^{aij} & \Lambda & k_D^{ain} \\ \mathrm{M} & & \mathrm{M} & & \mathrm{M} \\ k_D^{an1} & \Lambda & k_D^{anj} & \Lambda & k_D^{ann} \end{bmatrix} \tag{27}$$

Let the normalised matrix K_D^a fill to the unweight supermatrix to obtain the weighted supermatrix.

$$U^a = K_D^a U = \begin{bmatrix} k_D^{a11} \times u^{11} & \Lambda & k_D^{ai1} \times u^{1j} & \Lambda & k_D^{an1} \times u^{1n} \\ \mathrm{M} & & \mathrm{M} & & \mathrm{M} \\ k_D^{a1j} \times u^{i1} & \Lambda & k_D^{aij} \times u^{ij} & \Lambda & k_D^{anj} \times u^{in} \\ \mathrm{M} & & \mathrm{M} & & \mathrm{M} \\ k_D^{ain} \times u^{n1} & \Lambda & k_D^{ain} \times u^{nj} & \Lambda & k_D^{ann} \times u^{nn} \end{bmatrix} \tag{28}$$

S.7: *Limit the weighted supermatrix*. Limit the weighted supermatrix by raising it to a sufficiently large power h, until the supermatrix converges and become a long-term table supermatrix to get the global priority vectors, called analytic network process weights, such that $\lim_{h\to\infty}(U^a)^h$.

4.4. The VIKOR technique for ranking and enhancing alternatives

Opricovic (1998) suggested the VIKOR compromise ranking techniques an applicable strategy to implement within MCDM. Suppose the feasible alternatives are represented by $B_1, B_2, \ldots, B_k, \ldots, B_m$. The performance score of alternative B_k and the j^{th} criterion is denoted by e_{kj}; w_j is the weight (relative importance) of the j^{th} criterion, where $j = 1, 2, \ldots, n$, and n is the number of criteria. Development of the VIKOR technique started with the following form of Lp-metric (Wang & Tzeng, 2012; Ho, Tsai, Tzeng, Fang, 2011):

$$L_k^p = \left\{ \sum_{j=1}^{n} \left[v_j \left(\left| e_j^* - e_{kj} \right| \right) / \left(\left| e_j^* - e_{kj} \right| \right) \right]^p \right\}^{1/p} \tag{29}$$

where $1 \le p \le \infty$; $k = 1, 2, \ldots, m$weight v_j is obtained from the analytic network process. To formulate the ranking and gap measure, $L_k^{p=1}$(as S_k) and $L_k^{p=\infty}$(as Q_k) are utilised by VIKOR (Opricovic, 1998; Opricovic & Tzeng, 2004, 2007; Tzeng, Lin, & Opricovic, 2005; Tzeng, Teng, Chen, & Opricovic, 2002).

$$Y_k = L_k^{p=1} = \sum_{j=1}^{n} \left[v_j \left(\left| e_j^* - e_{kj} \right| \right) / \left(\left| e_j^* - e_j^- \right| \right) \right] \tag{30}$$

$$G_k = L_k^{p=\infty} = \max_j \left\{ \left(\left| e_j^* - e_{kj} \right| \right) / \left(\left| e_j^* - e_j^- \right| \right) | j = 1, 2, \ldots, n \right\} \tag{31}$$

The compromise solution $\min imum_k L_k^p$indicates that the synthesised gap that is the minimum and will be chosen for its value to be the closest to the desirable aspired level. In addition, the group utility is emphasised when p is small (such as $p = 1$). On the contrary, if p tends to become infinite, the individual maximal regrets/gaps obtain more importance in prior improvement (Freimer & Yu, 1976; Yu, 1973) in each

dimension/criterion. As a result, $\min_k S_k$ stresses the maximum group utility. However, $\min_k G_k$ accents on choosing the minimum from the maximum individual regrets/gaps. The compromise ranking algorithm VIKOR has four steps according to the above-mentioned concept.

S.1: *Obtain an aspired or tolerable level*. We compute the best e_j^* values (aspired level) and the worst e_j^- values (tolerable level) of all criterion functions, $j = 1, 2, \ldots, n$. Suppose the j^{th} function denotes benefits: $e_j^* = \max_k e_{kj}$ and $e_j^- = \min_k e_{kj}$ or these values can be set by decision makers(i.e., e_j^* is the aspired level and e_j^- is the worst value). In addition, an original rating matrix can be converted into a normalised weight-rating matrix by using the following equation:

$$t_{kj} = \left(\left|e_j^* - e_{kj}\right|\right) / \left(\left|e_j^* - e_j^-\right|\right) \tag{32}$$

S.2: *Compute mean of group utility and maximal regret*. The value scan be computed by $y_k = \sum_{j=1}^{n} v_j t_{kj}$ (the synthesised gap for all criteria) and $G_k = \max_j \{t_{kj} | j = 1, 2, \ldots, n\}$ (the maximal gap in k criterion for prior improvement).

S.3: *Calculate the index value*. The value can be computed by $R_k = x(Y_k - Y^*)/(Y^- - Y^*) + (1-x)(G_k - G^*)/(G^- - G^*)$ where $k = 1, 2, \ldots, m$. $S^* = \min_i S_i$ or setting $S^* = 0$ and $\boldsymbol{x}$ is presented as the weight of the strategy of the maximum group utility. Therefore, we also can re-write $R_k = xY_k + (1-x)G_k$ when $Y^* = 0$, $Y^- = 1$, $G^* = 0$ and $G^- = 1$.

S.4: *Rank or improve the alternatives for a compromise solution*. Order them in a decreasingly form by the value of Y_k, G_k and T_k. Propose the alternative $\left(B^{(1)}\right)$which is arranged by the measure $\min\{R_k | k = 1, 2, \ldots, m\}$ as a compromise solution when the following two conditions are satisfied: ***C1***. *Acceptable advantage*:$T\left(B^{(2)}\right) - \left(B^{(1)}\right) \geq 1/(m-1)$, where $B^{(2)}$is the second position in the alternatives ranked by T. ***C2***. *Acceptable stability in decision-making*: Alternative $B^{(1)}$ must also be the best ranked by Y_k or/and G_k. When one of the conditions is not satisfied, a set of compromise solutions is selected. The compromise solutions are composed of (1) alternatives $B^{(1)}$ and $B^{(2)}$ if only condition ***C2*** is not satisfied, or (2) alternatives $B^{(1)}, B^{(2)}, \ldots, B^{(M)}$ if condition ***C1*** is not satisfied. $B^{(M)}$is calculated by the relation $T\left(B^{(M)}\right) - T\left(B^{(1)}\right) < 1/(m-1)$ for maximum M (the positions of these alternatives are close).

The compromise-ranking technique (VIKOR) is used to characterise the compromise solution. This method is suitable for decision-makers since it offers a maximum group utility of the majority (indicated by min Y) and a maximal regret of a minimum number of opponent individuals (shown by min G). This model uses the DEMATEL and ANP processes in Ho et al. (2011), Opricovic (1998) of criteria with dependence and feedback and uses the VIKOR technique to obtain the compromise solution.

4.5. Analysis of data

Table 7 shows 62 tools extracted from the literature. The importance of each of the criteria was calculated using fuzzy screening. The responses from Fuzzy Screening questionnaire for each criteria must be arranged in a descending format. We show some of these in the following and the rest are shown in Table A1 in the Appendix.

U_1 = {K,PN,B,PN,PN,N,B,K,K,PN} U_2 = {K,PK,K, B,PK,B,PN,N,PK,PK}

U_3 = {N,PN,B,N,N,K,N,PK,N,PK} U_4 = {K,PK,B, WB,K,PN,K,PK,B,K}

U_5 = {WB,K,B,PN,K,B,PN,K,PK,K} U_6 = {PN,K,N, N,PN,K,PN,K,N,PN}

Given that the seven-item spectrum (q = 7) was used in this study, the questionnaire was forwarded to 10 experts (r = 10). Therefore, the consensus function is as follows:

$$B(k) = Int\left[1 + \left(k\frac{7-1}{10}\right)\right] \rightarrow B(k) = Int\left[1 + (.6k)\right] \quad k = 1, 2, \ldots, 10$$

Consensus function is as follows:

$$B(1) = Int[1 + (./6 \times 1)] = Int[1/67] = 1 \rightarrow Q_{A(1)} = S_1 \approx WB$$
$$B(2) = Int[1 + (./6 \times 2)] = Int[2/2] = 2 \rightarrow Q_{A(2)} = S_2 \approx B$$
$$B(3) = Int[1 + (./6 \times 3)] = Int[2/8] = 2 \rightarrow Q_{A(3)} = S_3 \approx B$$
$$B(4) = Int[1 + (./6 \times 4)] = Int[3/4] = 3 \rightarrow Q_{A(4)} = S_4 \approx PN$$
$$B(5) = Int[1 + (./6 \times 5)] = Int[4] = 4 \rightarrow Q_{A(5)} = S_5 \approx N$$
$$B(6) = Int[1 + (./6 \times 6)] = Int[4/6] = 4 \rightarrow Q_{A(6)} = S_6 \approx N$$
$$B(7) = Int[1 + (./6 \times 7)] = Int[5/2] = 5 \rightarrow Q_{A(7)} = S_7 \approx PK$$
$$B(8) = Int[1 + (./6 \times 8)] = Int[5/8] = 5 \rightarrow Q_{A(8)} = S_8 \approx PK$$
$$B(9) = Int[1 + (./6 \times 9)] = Int[6/4] = 6 \rightarrow Q_{A(9)} = S_9 \approx K$$
$$B(10) = Int[1 + (./6 \times 10)] = Int[7] = 7 \rightarrow Q_{A(10)} = S_{10} \approx WK$$

Some of the assessments acquired from fuzzy screening questionnaires are as follows and the rest are shown in Table A2 in the Appendix.

U_1 = Nax {WBΛK, BΛPN, BΛB, PNΛPN, NΛPN, NΛN, PKΛB, PKΛK, KΛN, WKΛPN} = K

U_2 = Nax {WBΛK, BΛPK, BΛK, PNΛB, NΛPK, NΛB, PKΛPN, PKΛN, KΛPK, WKΛPK} = PK

Table 7. The knowledge management tools in information security.

Cycle	No.	Knowledge management tools	Cycle	No.	Knowledge management tools
Knowledge creation and recording	1	Knowledge management readiness assessment	Knowledge Sharing and Diffusion	28	Document management system
	2	Data mining		29	Knowledge bases
	3	Meta data		30	Weblogs, web servers, explorers
	4	Video sharing		31	Knowledge storage
	5	Advanced search instrument		32	Social networking services
	6	Archive		33	Internet telephone, telephone, fax, video conferencing
	7	Locating systems and management expertise		34	Categorisation of knowledge in company
	8	Virtual team work		35	Locating systems and management expertise
	9	Organisational knowledge portal		36	Virtual team work
	10	Knowledge maps		37	Knowledge portal, intranet, and extranet
	11	Knowledge management maturity model		38	Video sharing
	12	Knowledgeable trainer		39	Exchange meetings after the completion of the project, story telling
	13	Brainstorming		40	Instant messaging, e-mails, chat rooms
	14	Personal knowledge management		41	Working associations and communities
	15	Weblogs		42	Knowledge café
	16	Internet telephone		43	Work flow management
	17	Learning and innovation management system		44	Categorisation of knowledge in company
	18	Knowledge café		45	Trainer, help of colleagues
	19	Exchange meetings after the completion of the project		46	Team work (physical work space)
	20	Categorisation of knowledge in company	Knowledge application	47	Trainer, help of colleagues
	21	Knowledge bases		48	Knowledge café
	22	Multimedia content development tool		49	Working associations and communities
	23	Annotations and comments		50	Team work (physical work space)
	24	Skill mining (expertise profile)		51	E-learning
	25	Knowledge clusters		52	Document management system
	26	Team work (physical work space)		53	Knowledge bases
	27	Working associations and communities		54	Advanced search instrument
				55	Locating systems and management expertise
				56	Knowledge clusters
				57	Virtual team work
				58	Knowledge portals, weblogs
				59	Expertise systems
				60	Decision support system
				61	Recommender systems
				62	Knowledge maps

U_3 = Nax {WBΛN, BΛPN, BΛB, PNΛN, NΛN, NΛK, PKΛN, PKΛPK, KΛN, WKΛPK} = N

U_4 = Nax {WBΛK, BΛPK, BΛB, PNΛWB, NΛK, NΛPN, PKΛK, PKΛPK, KΛB, WKΛK} = K

U_5 = Nax {WBΛWB, BΛK, BΛB, PNΛPN, NΛK, NΛB, PKΛPN, PKΛK, KΛPK, WKΛK} = K

U_6 = Nax {WBΛPN, BΛK, BΛN, PNΛN, NΛPN, NΛK, PKΛPN, PKΛK, KΛN, WKΛPN} = K

Table A3 indicates the significance of the 62 criteria. According to the questionnaires, factors with a very high degree of importance that are the output of the model were selected as the input for the integrated decision-making model. The other variables that have high, moderate, fairly moderate, low, and fairly low were removed and are not used as input for the integrated decision-making.

After selecting the integrated decision-making factors with fuzzy screening, we can draw the research conceptual model. Figure 2 indicates the research conceptual model.

The proposed evaluation framework can be used by any system (e.g., organisational information system) for a more effective assessment. We extracted 62 tools from the literature and calculated the importance of each of the criteria by 10 experts who respond to the fuzzy screening questionnaires in the fuzzy screening method. According to the questionnaires, 20 knowledge management tools in information security that had very high degree of importance and were the model output were selected as the input for the integrated decision-making model (Figure 2). It is clear from Table A2 that 42 knowledge management tools had high, moderate, fairly moderate, low, and fairly low degree of importance. Figure 2 shows the conceptual model of the paper based on the tools extracted by fuzzy screening method.

The results show that all aspects (cycles of knowledge management) and subgoals (knowledge management tools) are dependent and relative, according to Table A4–A12. Figure 3 indicates their causal relationship, and it can aid researchers and executives examine the relationships among these cycles and tools. Figure 3 indicates that knowledge creation and recording and knowledge application affect knowledge sharing and diffusion more than

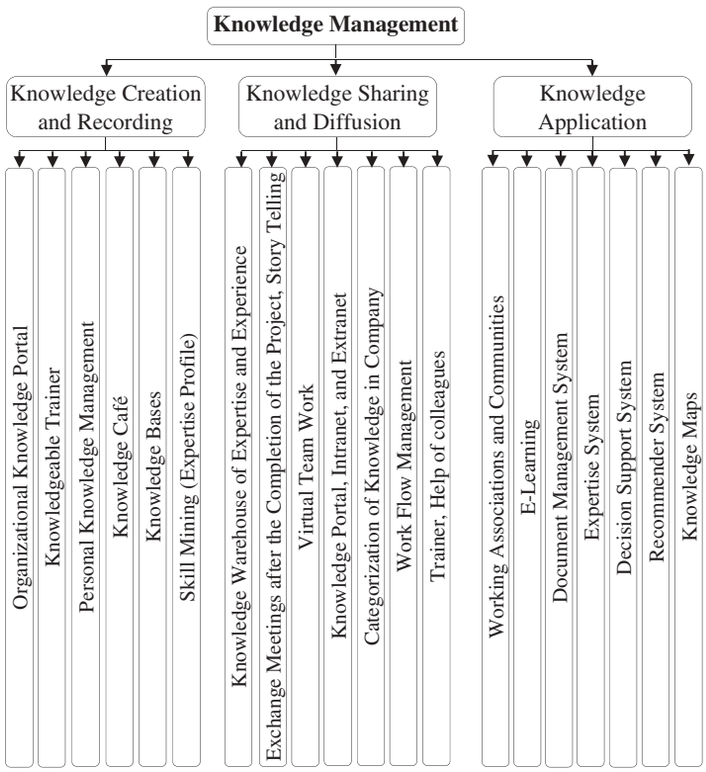

Figure 2. Conceptual model.

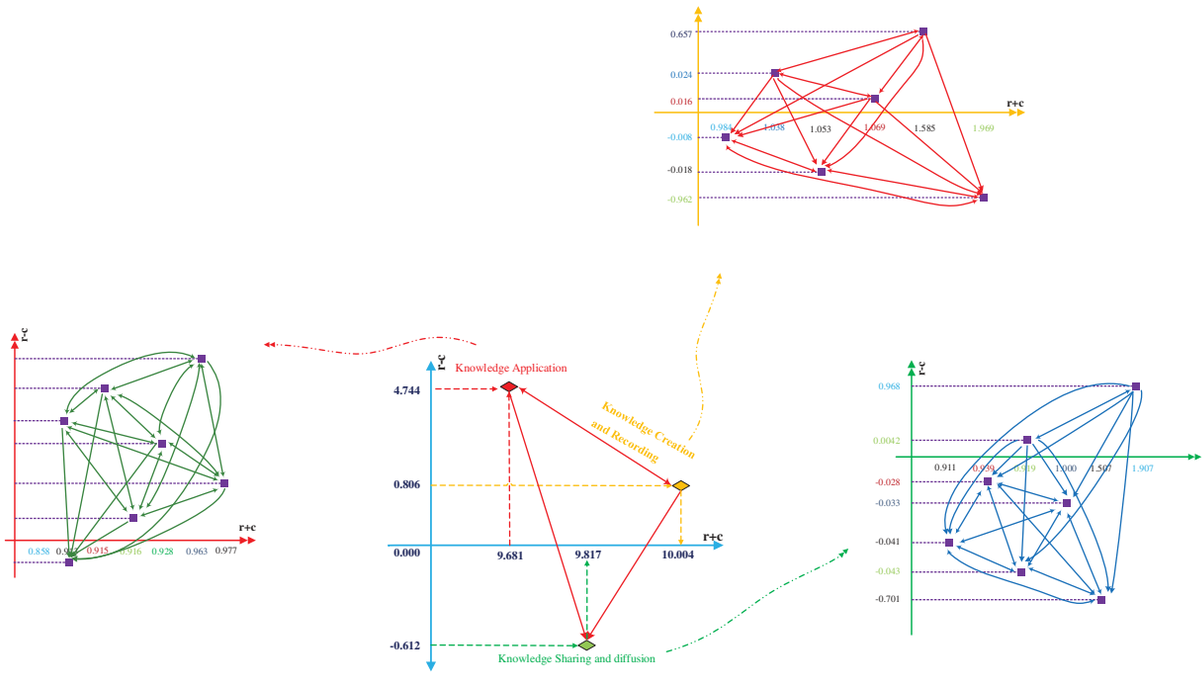

Figure 3. Relationship of knowledge management cycles and tools.

knowledge sharing and diffusion. Knowledge creation and recording and knowledge application expand their aspects as the upper and left hand portion of Figure 3. For the knowledge management cycles, the p – z values for knowledge creation and recording and knowledge application are positive, which means that they affect knowledge sharing and diffusion. In other hands, when enterprises adopt these cycles (knowledge management tools in information security), knowledge creation and recording and knowledge application will influence the achievement or failure of the other knowledge management cycles (knowledge management tools in information security). Similarly, knowledge sharing and diffusion expands its aspects as the right hand portion of Figure 3. Among the different aspects of knowledge

creation and recording, for example, the r – c values for organisational knowledge portal, knowledgeable trainer, and skill mining are positive, which means that these four tools affect the other tools in the knowledge creation and recording cycle more than the others do. Thus, when enterprises adopt these tools, the tools that can influence others should be adopted first. Thus, when the organisation has adopted knowledge management tools in information systems, these tools in information systems assessment should be used to identify the lower performances of tools (subgoals in the knowledge management cycles) that need enhancement. Furthermore, when the tools with lower performances are improved, the influencers should also be checked again. For example, knowledge café, personal KM, and knowledge bases in the same cluster (knowledge management cycles) should be given priority to be improved in this empirical case, respectively. However, the influencers organisational knowledge portal, knowledgeable trainer, and skill mining in subgoal knowledge creation and recording (because they affect personal KM, knowledge café, and knowledge bases) should be checked again. Finally, in the impact relations map, (p + z) provides an index of the strength of influences given and received, that is, (p + z) indicates the degree that each dimension and criteria has in the problem.

After recognising the structural relationship among the factors of knowledge management tools in information systems, the analytic network process technique is used to obtain criteria influence weights. The results of the paper indicate the weights of any tool in knowledge management cycles in two levels (i.e., the global weights that show the weights of tools with respect to other tools in the whole model and the local weights that show the weights of tools in certain cycle). Table A13 shows the global and local weights of knowledge management tools. We see that knowledge maps, decision support system, and document management system have the highest global weight and virtual team work, work flow management, trainer, and help of colleagues have the least global weight, respectively. In the local weight level, Table A13 shows that in the knowledge creation and recording cycle, for example, knowledge bases has the highest local weight and personal knowledge management has the lowest local weight.

Consequently, using the VIKOR technique combines the aspects that have dependence and feedback characteristics to acquire the ranking indices of performances and risks of subgoals, as indicated in Table A14–A18. Thus, among the tools, knowledge bases by priority equal 1 is the closest to the ideal/aspired level, whereas knowledge trainer by priority equal 20 is the farthest from the ideal/aspired level. If executives want to enhance the tools according to their performances, then knowledge trainer should be given priority during selection. However, when a manager chooses the subgoal with lower performances for enhancement, the influencers among its aspects or subgoals should be thoroughly considered.

In Table A9 and Figure 3, subgoals of knowledge creation and recording cycle are shown For example, organisational knowledge portal, knowledgeable trainer, and skill mining affect personal KM, knowledge café, and knowledge bases more than personal knowledge management. In addition, knowledge café and knowledge bases affect organisational knowledge portal, knowledgeable trainer, and skill mining. Therefore, if each tool for which p – z is negative is selected for improvement, the tool with positive p – z should be examined to identify whether it should be improved simultaneously. Generally, if personal KM, knowledge café, and knowledge bases are performing very well, then organisational knowledge portal, knowledgeable trainer, and skill mining will perform very well too.

To sum up, the hybrid model that combines DEMATEL with analytic network process has been widely applied in MCDM problems. In this research, the fuzzy screening technique is applied to select knowledge management tools with very high degree of importance as the input for the MCDM hybrid model. DEMATEL can be applied for dealing with the inner dependencies of the criteria. It can also generate more important information for decision-making. For these reasons, combining analytic network process and DEMATEL give successful consequences in making strategic decisions. Therefore, the analytic network process technique is applied to overcome the problems of dependence and feedback. In addition, the weights acquire from the analytic network process and VIKOR techniques are applied to obtain the ranking index.

5. Conclusion

Considering the dependence of the organisation on information technology, information system security is one of the most important challenges of today's organisations. Although most organisations use security technologies, they have come to the conclusion that technology alone is not enough and information security technologies alone only address a small part of the information risk problem. In addition, it does not reduce the risk of information effectively. The main threat for organisational security is rooted in employees who do not have adequate knowledge of organisational security. Thus, one of the most important missions of knowledge management is the conversion of the organisation into a learning and sharing one. This is met by the establishment of knowledge flow between human

resources by using tools and techniques in different units. Since knowledgeable human resources are the most important part of an organisation, organisations are concerned with knowledge application and transfer. To this end, they use various techniques and tools for transferring and sharing. According to the importance of the topic, 62 knowledge management tools and techniques were identified. Then, 20 tools were taken into account by using expert opinions by using fuzzy screening through interviews and questionnaires. ANP, DEMATEL, and VIKOR were employed to weigh, determine the internal relationships, and rank the tools. According to the results in knowledge creation and recording, "knowledge bases" was the most important. In sharing diffusion and application, "categorization of knowledge" and "knowledge maps" scored the top, respectively. Organisations can create a friendly and trustworthy environment in order to invest on software and hardware infrastructures for exchanging and creating knowledge.

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Appendix

Table A1. The responses of the experts to the fuzzy screening questionnaires (U_{7}- U_{62}).

U_7 = {FH,M,L,M,M,FM,M,M,M,M}	U_{35} = {VL,FM,L,VL,M,M,L,M,M,FM}
U_8 = {FM,VL,L,VL,FM,FM,L,FM,VL,L}	U_{36} = {L,L,M,FH,VH,VH,VH,VL,M,VH}
U_9 = {L,VH,H,VH,H,VH,VH,VH,FM,H}	U_{37} = {VH,FM,H,VH,FM,M,M,M,H,VH}
U_{10} = {M,L,M,FM,M,L,M,FM,VL,M}	U_{38} = {H,FH,H,L,FH,L,FM,M,FH,FH}
U_{11} = {FH,FM,L,VH,L,M,H,VH,L,FM}	U_{39} = {FM,L,H,L,VH,VH,VH,VH,VH,H}
U_{12} = {VL,FM,L,VH,M,M,L,M,M,FM}	U_{40} = {FM,VL,L,VL,FM,FM,L,FM,VL,L}
U_{13} = {FH,M,VL,M,FM,FH,VL,FH,FM,FH}	U_{41} = {VL,FM,L, H,H,VL,FH,FM, H,H}
U_{14} = {H, VH,H,L,VH,L,VH,VH,FM,VH}	U_{42} = {FM,VL,L,VL,FM,FM,L,FM,VL,L}
U_{15} = {H,FH,H,L,FH,L,FM,M,FH,FH}	U_{43} = {VH,H,VH,FM,VH,L,FM,VH,FH,VH}
U_{16} = {FM,VL,L,VL,FM,FM,L,FM,VL,L}	U_{44} = {VL,FM,L,VH,M,M,L,M,M,FM}
U_{17} = {VL,H,L,FM,H,L,FM,H,FH,H}	U_{45} = {M,FH,M,M,VH,M,VH,FH,VH,H}
U_{18} = {VL,FM,L,VH,M,M,L,M,M,FM}	U_{46} = {H,FH,H,L,FH,L,FM,M,FH,FH}
U_{19} = {H,FH,H,L,FH,L,FM,M,FH,FH}	U_{47} = {L,L,H,M,H,VH,VH,H,FM,H}
U_{20} = {M,FM,L,M,M,H,M,FH,M,FH}	U_{48} = {VL,FM,VL,FM,M,L,FM,VL,FM,VL}
U_{21} = {FM,VH,L,VL,VH,FM,VH,FM,VH,L}	U_{49} = {FM,VH,L,VH,VH,FM,L,FM,VH,L}
U_{22} = {VL,FM,L,H,M,M,L,M,M,FM}	U_{50} = {H,FH,H,L,FH,L,FM,M,FH,FH}
U_{23} = {L,L,H,M,H,VH,VH,H,FM,H}	U_{51} = {VH,VL,VL,VH,FM,H,VH,FM,VL,VH}
U_{24} = {VL,VH,L,VL,VH,L,FM,VH,VH,H}	U_{52} = {VH,FM,VH,VH,M,M,VH,M,VH,FM}
U_{25} = {FM,VL,L,VL,FM,FM,L,FM,VL,L}	U_{53} = {VL,FM,FM,FH,M, H,H, H,FM,M}
U_{26} = {H,FH,H,L,FH,L,FM,M,FH,FH}	U_{54} = {H,M,VH,M,M,M,VH,M,M,VH}
U_{27} = {L, H,H,M,FM,H, H,FH,M,VH}	U_{55} = {M,FM,VL,VH,VH,VL,VH,FM,VL,FM}
U_{28} = {FM,H, H,VL,L,FM,H,FM,L,L}	U_{56} = {H,FH,H,L,FH,L,FM,M,FH,FH}
U_{29} = {FM,VL,L,VL,FM,FM,L,FM,VL,L}	U_{57} = {H,VH,L,FM, H,FH, H,H,FM,H}
U_{30} = {H,FH,H,L,FH,L,FM,M,FH,FH}	U_{58} = {FM,VL,L,VL,FM,FM,L,FM,VL,L}
U_{31} = {VL,FM,VH,L,VH,M,VH,M,M,VL}	U_{59} = {FM,VH,VL,FH,VH,FM,M,H,VH,VH}
U_{32} = {H,L,L,FM,VL, H, H,H,FM,FM}	U_{60} = {L,VH,L,VH,VH,VH,FM,VH,L,FM}
U_{33} = {VL,H,L,FM,H,L,FM,H,FH,H}	U_{61} = {VL,VL,L,VL,H,FM,L,FM,VL,L}
U_{34} = {H,FM,L,M,M,L,L,M, H,FM}	U_{62} = {FH,VH,H,L,VH,L,VH,M,FH,H}

Table A2. The assessments acquired from the fuzzy screening questionnaires (U_7- U_{62}).

U_7 = max {VL∧FH, L∧M, L∧L, FM∧M, M∧M, M∧FM, FH∧M, FH∧M, H∧M, VH∧M} = M
U_8 = max {VL∧FM, L∧VL, L∧L, FM∧VL, M∧FM, M∧FM, FH∧L, FH∧FM, H∧VL, VH∧L} = FH
U_9 = max {VL∧L, L∧VH, L∧H, FM∧VH, M∧H, M∧VH, FH∧VH, FH∧VH, H∧FM, VH∧H} = VH
U_{10} = max {VL∧M, L∧L, L∧M, FM∧FM, M∧M, M∧L, FH∧M, FH∧FM, H∧VL, VH∧M} = M
U_{11} = max {VL∧FH, L∧FM, L∧L, FM∧VH, M∧L, M∧M, FH∧H, FH∧H, H∧L, VH∧FM} = H
U_{12} = max {VL∧VL, L∧FM, L∧L, FM∧VH, M∧M, M∧M, FH∧L, FH∧M, H∧M, VH∧FM} = VH
U_{13} = max {VL∧FH, L∧M, L∧VL, FM∧M, M∧FM, M∧FH, FH∧VL, FH∧FH, H∧FM, VH∧FH} = FH
U_{14} = max {VL∧H, L∧VH, L∧H, FM∧L, M∧VH, M∧L, FH∧VH, FH∧VH, H∧FM, VH∧VH} = VH
U_{15} = max {VL∧H, L∧FH, L∧H, FM∧L, M∧FH, M∧L, FH∧FM, FH∧M, H∧FH, VH∧FH} = FH
U_{16} = max {VL∧FM, L∧VL, L∧L, FM∧VL, M∧FM, M∧FM, FH∧L, FH∧FM, H∧VL, VH∧L} = FH
U_{17} = max {VL∧VL, L∧H, L∧L, FM∧FM, M∧H, M∧L, FH∧FM, FH∧H, H∧FH, VH∧H} = H
U_{18} = max {VL∧VL, L∧FM, L∧L, FM∧VH, M∧M, M∧M, FH∧L, FH∧M, H∧M, VH∧FM} = VH
U_{19} = max {VL∧H, L∧FH, L∧H, FM∧L, M∧FH, M∧L, FH∧FM, FH∧M, H∧FH, VH∧FH} = FH
U_{20} = max {VL∧M, L∧FM, L∧L, FM∧VH, M∧M, M∧M, FH∧L, FH∧M, H∧M, VH∧FM} = M
U_{21} = max {VL∧FM, L∧VH, L∧L, FM∧VL, M∧VH, M∧FM, FH∧VH, FH∧FM, H∧VH, VH∧L} = VH
U_{22} = max {VL∧VL, L∧FM, L∧L, FM∧H, M∧M, M∧M, FH∧L, FH∧M, VH∧FM} = M
U_{23} = max {VL∧L, L∧L, L∧H, FM∧M, M∧H, M∧VH, FH∧VH, FH∧H, H∧FM, VH∧H} = H
U_{24} = max {VL∧VL, L∧VH, L∧L, FM∧VL, M∧VH, M∧L, FH∧FM, FH∧VH, H∧VH, VH∧H} = VH
U_{25} = max {VL∧FM, L∧VL, L∧L, FM∧VL, M∧FM, M∧FM, FH∧L, FH∧FM, H∧VL, VH∧L} = FH
U_{26} = max {VL∧H, L∧FH, L∧H, FM∧L, M∧FH, M∧L, FH∧FM, FH∧M, H∧FH, VH∧FH} = FH
U_{27} = max {VL∧FM, L∧VL, L∧L, FM∧VL, M∧FM, M∧FM, FH∧L, FH∧FM, H∧VL, VH∧L} = FH
U_{28} = max {VL∧FM, L∧H, L∧H, FM∧VL, M∧L, M∧FM, FH∧H, FH∧FM, H∧L, VH∧L} = H
U_{29} = max {VL∧FM, L∧VL, L∧L, FM∧VL, M∧FM, M∧FM, FH∧L, FH∧FM, H∧VL, VH∧L} = FH
U_{30} = max {VL∧H, L∧FH, L∧H, FM∧L, M∧FH, M∧L, FH∧FM, FH∧M, H∧FH, VH∧FH} = FH
U_{31} = max {VL∧VL, L∧FM, L∧VH, FM∧L, M∧VH, M∧M, FH∧VH, FH∧M, H∧M, VH∧VL} = VH
U_{32} = max {VL∧H, L∧L, L∧L, FM∧FM, M∧VL, M∧H, FH∧H, FH∧H, H∧FM, VH∧FM} = H
U_{33} = max {VL∧VH, L∧H, L∧L, FM∧FM, M∧H, M∧L, FH∧FM, FH∧H, H∧FH, VH∧H} = H
U_{34} = max {VL∧H, L∧FM, L∧L, FM∧M, M∧M, M∧L, FH∧L, FH∧M, H∧H, VH∧FM} = M
U_{35} = max {VL∧VL, L∧FM, L∧L, FM∧VL, M∧M, M∧M, FH∧L, FH∧M, H∧M, VH∧FM} = FH
U_{36} = max {VL∧L, L∧L, L∧M, FM∧FH, M∧VH, M∧VH, FH∧VH, FH∧VL, H∧M, VH∧VH} = VH
U_{37} = max {VL∧VH, L∧FM, L∧H, FM∧VH, M∧FM, M∧M, FH∧M, FH∧M, H∧H, VH∧VH} = VH
U_{38} = max {VL∧H, L∧FH, L∧H, FM∧L, M∧FH, M∧L, FH∧FM, FH∧M, H∧FH, VH∧FH} = FH
U_{39} = max {VL∧FM, L∧L, L∧H, FM∧L, M∧VH, M∧VH, FH∧VH, FH∧VH, H∧VH, VH∧H} = VH
U_{40} = max {VL∧FM, L∧VL, L∧L, FM∧VL, M∧FM, M∧FM, FH∧L, FH∧FM, H∧VL, VH∧L} = FH
U_{41} = max {VL∧VL, L∧FM, L∧L, FM∧H, M∧H, M∧VL, FH∧FH, FH∧FM, H∧H, VH∧H} = H
U_{42} = max {VL∧FM, L∧VL, L∧L, FM∧VL, M∧FM, M∧FM, FH∧L, FH∧FM, H∧VL, VH∧L} = FH
U_{43} = max {VL∧VH, L∧H, L∧VH, FM∧FM, M∧VH, M∧L, FH∧FM, FH∧VH, H∧FH, VH∧VH} = VH
U_{44} = max {VL∧VL, L∧FM, L∧L, FM∧VH, M∧M, M∧M, FH∧L, FH∧M, H∧M, VH∧FM} = VH
U_{45} = max {VL∧M, L∧FH, L∧M, FM∧M, M∧VH, M∧M, FH∧VH, FH∧FH, H∧VH, VH∧H} = VH
U_{46} = max {VL∧H, L∧FH, L∧H, FM∧L, M∧FH, M∧L, FH∧FM, FH∧M, H∧FH, VH∧FH} = FH
U_{47} = max {VL∧L, L∧L, L∧H, FM∧M, M∧H, M∧VH, FH∧VH, FH∧H, H∧FM, VH∧H} = H
U_{48} = max {VL∧VL, L∧FM, L∧VL, FM∧FM, M∧M, M∧L, FH∧FM, FH∧VL, H∧FM, VH∧VL} = FM
U_{49} = max {VL∧FM, L∧VH, L∧L, FM∧VH, M∧VH, M∧FM, FH∧L, FH∧FM, H∧VH, VH∧L} = VH
U_{50} = max {VL∧H, L∧FH, L∧H, FM∧L, M∧FH, M∧L, FH∧FM, FH∧M, H∧FH, VH∧FH} = FH
U_{51} = max {VL∧VH, L∧VL, L∧VL, FM∧VH, M∧FM, M∧H, FH∧VH, FH∧FM, H∧VL, VH∧VH} = VH
U_{52} = max {VL∧VH, L∧FM, L∧VH, FM∧VH, M∧M, M∧M, FH∧VH, FH∧M, H∧VH, VH∧FM} = VH
U_{53} = max {VL∧VL, L∧FM, L∧FM, FM∧FH, M∧M, M∧H, FH∧H, FH∧H, H∧FM, VH∧M} = H
U_{54} = max {VL∧H, L∧M, L∧VH, FM∧M, M∧M, M∧M, FH∧VH, FH∧M, H∧M, VH∧VH} = M
U_{55} = max {VL∧M, L∧FM, L∧VL, FM∧VH, M∧VH, M∧VL, FH∧VH, FH∧FM, H∧VL, VH∧FM} = VH
U_{56} = max {VL∧H, L∧FH, L∧H, FM∧L, M∧FH, M∧L, FH∧FM, FH∧M, H∧FH, VH∧FH} = FH
U_{57} = max {VL∧H, L∧VH, L∧L, FM∧FM, M∧H, M∧FH, FH∧H, FH∧H, H∧FM, VH∧H} = H
U_{58} = max {VL∧FM, L∧VL, L∧L, FM∧VL, M∧FM, M∧FM, FH∧L, FH∧FM, H∧VL, VH∧L} = FH
U_{59} = max {VL∧FM, L∧VH, L∧VL, FM∧FH, M∧VH, M∧FM, FH∧M, FH∧H, H∧VH, VH∧VH} = VH
U_{60} = max {VL∧L, L∧VH, L∧L, FM∧VH, M∧VH, M∧VH, FH∧FM, FH∧VH, H∧L, VH∧FM} = VH
U_{61} = max {VL∧VL, L∧VL, L∧L, FM∧VL, M∧H, M∧FM, FH∧L, FH∧FM, H∧VL, VH∧L} = H
U_{62} = max {VL∧FH, L∧VH, L∧H, FM∧L, M∧VH, M∧L, FH∧VH, FH∧M, H∧FH, VH∧H} = VH

Table A3. The importance of the knowledge management tools.

Factor	Importance	Factor	Importance	Factor	Importance	Factor	Importance	Factor	Importance	Factor	Importance	Factor	Importance	Factor	Importance
1	H	9	**VH**	17	H	25	FH	33	H	41	H	49	**VH**	57	H
2	FH	10	M	18	**VH**	26	FH	34	M	42	FH	50	FH	58	FH
3	M	11	H	19	FH	27	FH	35	FH	43	**VH**	51	**VH**	59	**VH**
4	H	12	**VH**	20	M	28	H	36	**VH**	44	**VH**	52	**VH**	60	**VH**
5	H	13	FH	21	**VH**	29	FH	37	**VH**	45	**VH**	53	H	61	H
6	H	14	**VH**	22	M	30	FH	38	FH	46	FH	54	M	62	**VH**
7	M	15	FH	23	H	31	**VH**	39	**VH**	47	H	55	**VH**		
8	FH	16	FH	24	**VH**	32	H	40	FH	48	FM	56	FH		

Table A4. Influence matrix of knowledge management cycles.

Knowledge management cycles	Knowledge creation and recording	Knowledge sharing and diffusion	Knowledge application	Sum
Knowledge creation and recording	0	3.51	2.16	5.67
Knowledge sharing and diffusion	2.16	0	2.21	4.28
Knowledge application	4.23	2.11	0	4.27
Sum	4.23	5.62	4.37	

Table A5. Full direct/indirect influence matrix of knowledge management cycles.

Knowledge management cycles	Knowledge creation and recording	Knowledge sharing and diffusion	Knowledge application
Knowledge creation and recording	0	0.619	0.381
Knowledge sharing and diffusion	0.365	0	0.39
Knowledge application	0.381	0.372	0

Table A6. Total influence matrix of knowledge management cycles.

Knowledge management cycles	Knowledge creation and recording	Knowledge sharing and diffusion	Knowledge application	r	$r + c$	$r - c$
Knowledge creation and recording	1.546	2.010	1.849	5.405	10.004	0.806
Knowledge sharing and diffusion	1.501	1.488	1.613	4.602	9.817	−0.612
Knowledge application	1.552	1.716	1.476	4.744	9.681	4.744
c	4.599	5.214	4.938			

Table A7. Influence matrix of knowledge management tools.

Tool name	Organisational knowledge portal	Knowledgeable trainer	Personal KM	Knowledge café	Knowledge bases	Skill mining	Knowledge storage	Virtual team work	Knowledge portal…	Exchange meetings…	Work flow management	Categorisation of knowledge	Trainer, help of colleagues	Working associations and communities	E-learning	Document management system	Expertise systems	Decision support system	Recommender systems	Knowledge maps	Sum
Organisational knowledge portal	0	2.6	2.73	2.25	2.17	1.76	2.73	2.09	1.36	1.42	1.77	2.52	2.38	2.38	1.8	1.88	1.81	2.04	2.25	1.63	39.57
Knowledgeable trainer	2.19	0	2.29	2.21	2.05	1.94	2.7	1.75	1.92	1.55	1.58	2.35	2.49	2.7	2.22	1.67	2.51	2.24	2.03	1.67	40.06
Personal KM	2.68	2.68	0	2.17	2.09	2.17	2.03	1.97	2.15	1.81	2.43	1.58	1.81	2	1.77	2.03	1.61	1.94	1.72	1.64	38.28
Knowledge café	2.14	1.91	1.7	0	2.32	2.35	2.5	2.02	1.97	1.89	1.63	2.21	1.94	1.77	2.21	1.55	1.72	1.81	2.06	1.39	37.09
Knowledge Bases	2.24	2.56	1.72	2.68	0	2.08	2.25	1.81	1.8	1.55	1.65	2.12	1.67	1.67	2.36	1.04	1.78	1.42	2.17	1.78	36.35
Skill mining	1.62	2.76	2.83	1.68	2.71	0	2.07	1.47	1.78	54.1	1.66	1.69	2.21	2.07	2.26	2.13	1.51	1.46	1.81	1.69	89.51
Knowledge storage	2.81	2.85	1.77	2.55	2.6	1.6	0	1.4	1.52	1.53	1.75	1.48	1.48	1.87	1.65	1.83	1.81	1.9	1.55	2.13	36.08
Virtual team Work	2.44	2.09	2.93	1.89	1.94	1.71	2.29	0	1.83	1.34	1.75	2.16	1.53	1.87	1.81	1.7	1.31	1.58	2.01	1.37	35.55
Knowledge portal…	1.34	1.66	2.33	1.95	1.84	1.93	1.41	1.66	0	2.03	1.96	1.77	1.51	1.55	1.75	1.91	1.7	1.93	1.58	1.82	33.63
Exchange meetings…	1.23	1.3	1.77	1.65	1.19	1.35	1.79	1.61	2.38	0	2.21	1.79	1.6	0.142	1.95	1.62	1.66	1.46	1.55	1.66	29.912
Work flow management	1.27	1.77	1.75	1.97	1.68	1.63	1.58	1.46	2.36	2.48	0	1.7	1.63	1.52	1.64	1.78	1.58	1.52	1.33	1.83	32.48
Categorisation of knowledge	1.77	1.87	2.14	1.68	1.38	1.38	1.6	1.51	1.48	2.81	1.66	0	1.64	1.85	1.62	1.52	1.39	1.94	1.27	1.66	32.17
Trainer, help of colleagues	2.39	2.14	2.12	79.1	1.66	1.49	1.37	1.49	1.81	1.55	1.79	2.1	0	1.87	2.07	1.26	1.88	1.88	2.04	1.32	111.33
Working associations and communities	2.24	2.41	2.08	1.31	1.46	1.37	1.87	1.53	1.97	1.61	2.26	1.63	2.24	0	1.41	1.39	1.83	1.9	1.6	1.64	33.75
E-learning	2.47	2.05	2.08	2.24	1.77	1.9	2.37	1.96	1.57	1.6	1.54	2.03	1.88	1.96	0	1.7	1.65	1.86	1.89	1.77	36.29
Document management system	1.34	1.23	1.97	1.89	1.82	1.7	1.97	1.96	2.63	2.12	2.65	1.75	1.73	1.68	1.79	0	1.47	1.45	1.69	1.7	34.54
Expertise systems	2.1	2.1	1.49	1.7	1.73	1.73	2.03	1.41	1.88	1.73	1.54	1.49	2.03	2.38	2.24	1.7	0	1.97	1.76	1.6	34.61
Decision support system	2.26	2.8	2.12	2.48	2.06	2.64	2.5	1.81	1.53	1.73	1.75	1.41	1.72	2.26	1.07	1.51	1.96	0	1.62	2.13	37.36
Recommender systems	1.97	2.36	2.1	1.99	2.21	1.49	1.56	1.28	1.75	1.28	1.63	1.53	1.75	1.56	2.28	2.53	2.03	2.15	0	1.55	35
Knowledge maps	1.34	0.158	2.14	1.77	1.82	1.42	1.56	1.96	1.82	2.18	2.44	1.79	1.42	1.54	1.84	2.13	1.53	1.52	1.68	0	32.058
Sum	37.84	39.298	40.06	115.16	36.5	33.64	38.18	32.15	35.51	86.31	35.65	35.1	34.66	34.642	35.74	32.88	32.74	33.97	33.61	31.98	

Table A8. Full direct/indirect influence matrix of knowledge management tools.

Tool name	organisational knowledge portal	Knowledgeable trainer	Personal KM	Knowledge café	Knowledge bases	Skill mining	Knowledge storage	Virtual team work	Knowledge portal…	Exchange meetings…	Work flow management	categorisation of knowledge	Trainer, help of colleagues	Working associations and communities	E-learning	Document management system	Expertise systems	Decision support system	Recommender systems	Knowledge maps
organisational knowledge portal	0	0.023	0.024	0.020	0.019	0.015	0.024	0.018	0.012	0.012	0.015	0.022	0.021	0.021	0.016	0.016	0.016	0.018	0.020	0.014
Knowledgeable trainer	0.019	0	0.020	0.019	0.018	0.017	0.023	0.015	0.017	0.013	0.014	0.020	0.022	0.023	0.019	0.015	0.022	0.019	0.018	0.015
Personal KM	0.023	0.023	0	0.019	0.018	0.019	0.018	0.017	0.019	0.016	0.021	0.014	0.016	0.017	0.015	0.018	0.014	0.017	0.015	0.014
Knowledge café	0.019	0.017	0.015	0	0.020	0.020	0.022	0.018	0.017	0.016	0.014	0.019	0.017	0.015	0.019	0.013	0.015	0.016	0.018	0.012
Knowledge bases	0.019	0.022	0.015	0.023	0	0.018	0.020	0.016	0.016	0.013	0.014	0.018	0.015	0.015	0.020	0.009	0.015	0.012	0.019	0.015
Skill mining	0.014	0.024	0.025	0.015	0.024	0	0.018	0.013	0.015	0.470	0.014	0.015	0.019	0.018	0.020	0.018	0.013	0.013	0.016	0.015
Knowledge storage	0.024	0.025	0.015	0.022	0.023	0.014	0	0.012	0.013	0.013	0.015	0.013	0.013	0.016	0.014	0.016	0.016	0.016	0.013	0.018
Virtual team work	0.021	0.018	0.025	0.016	0.017	0.015	0.020	0	0.016	0.012	0.015	0.019	0.013	0.016	0.016	0.015	0.011	0.014	0.017	0.012
Knowledge portal…	0.012	0.014	0.020	0.017	0.016	0.017	0.012	0.014	0	0.018	0.017	0.015	0.013	0.013	0.015	0.017	0.015	0.017	0.014	0.016
Exchange meetings…	0.011	0.011	0.015	0.014	0.010	0.012	0.016	0.014	0.021	0	0.019	0.016	0.014	0.001	0.017	0.014	0.014	0.013	0.013	0.014
Work flow management	0.011	0.015	0.015	0.017	0.015	0.014	0.014	0.013	0.020	0.022	0	0.015	0.014	0.013	0.014	0.015	0.014	0.013	0.012	0.016
Categorisation of knowledge	0.015	0.016	0.019	0.015	0.012	0.012	0.014	0.013	0.013	0.024	0.014	0	0.014	0.016	0.014	0.013	0.012	0.017	0.011	0.014
Trainer, Help of colleagues	0.021	0.019	0.018	0.687	0.014	0.013	0.012	0.013	0.016	0.013	0.016	0.018	0	0.016	0.018	0.011	0.016	0.016	0.018	0.011
Working Associations and Communities	0.019	0.021	0.018	0.011	0.013	0.012	0.016	0.013	0.017	0.014	0.020	0.014	0.019	0	0.012	0.012	0.016	0.016	0.014	0.014
E-learning	0.021	0.018	0.018	0.019	0.015	0.016	0.021	0.017	0.014	0.014	0.013	0.018	0.016	0.017	0	0.015	0.014	0.016	0.016	0.015
Document management system	0.012	0.011	0.017	0.016	0.016	0.015	0.017	0.017	0.023	0.018	0.023	0.015	0.015	0.015	0.016	0	0.013	0.013	0.015	0.015
Expertise systems	0.018	0.018	0.013	0.015	0.015	0.015	0.018	0.012	0.016	0.015	0.013	0.013	0.018	0.021	0.019	0.015	0	0.017	0.015	0.014
Decision support system	0.020	0.024	0.018	0.022	0.018	0.023	0.022	0.016	0.013	0.015	0.015	0.012	0.015	0.020	0.009	0.013	0.017	0	0.014	0.018
Recommender systems	0.017	0.020	0.018	0.017	0.019	0.013	0.014	0.011	0.015	0.011	0.014	0.013	0.015	0.014	0.020	0.022	0.018	0.019	0	0.013
Knowledge maps	0.012	0.001	0.019	0.015	0.016	0.012	0.014	0.017	0.016	0.019	0.021	0.016	0.012	0.013	0.016	0.018	0.013	0.013	0.015	0

Table A9. Total influence matrix of knowledge management tools.

Tool name	organisational knowledge portal	Knowledgeable trainer	Personal KM	Knowledge café	Knowledge bases	Skill mining	Knowledge storage	Virtual team work	Knowledge portal…	Exchange meetings…	Work flow management	categorisation of knowledge	Trainer, help of colleagues	Working associations and communities	E-learning	Document management system	Expertise systems	Decision support system	Recommender systems	Knowledge maps	r	$r + c$	$r - c$
organisational knowledge portal	0.009	0.031	0.032	0.046	0.028	0.023	0.032	0.026	0.021	0.030	0.023	0.030	0.028	0.028	0.024	0.024	0.023	0.025	0.027	0.022	0.531	1.038	0.024
Knowledgeable trainer	0.028	0.010	0.029	0.047	0.027	0.025	0.032	0.023	0.025	0.032	0.023	0.028	0.029	0.031	0.028	0.022	0.029	0.027	0.025	0.022	0.543	1.069	0.016
Personal KM	0.031	0.032	0.009	0.043	0.026	0.027	0.026	0.024	0.026	0.035	0.029	0.022	0.023	0.025	0.023	0.025	0.022	0.025	0.023	0.021	0.518	1.053	−0.018
Knowledge café	0.026	0.025	0.024	0.025	0.028	0.028	0.029	0.024	0.025	0.036	0.022	0.027	0.025	0.023	0.027	0.020	0.022	0.023	0.026	0.019	0.503	1.969	−0.962
Knowledge bases	0.027	0.030	0.024	0.045	0.008	0.025	0.027	0.022	0.023	0.032	0.022	0.026	0.022	0.021	0.028	0.016	0.022	0.019	0.026	0.022	0.488	0.984	−0.008
Skill mining	0.030	0.041	0.042	0.055	0.038	0.016	0.036	0.029	0.035	0.480	0.033	0.031	0.036	0.029	0.037	0.034	0.029	0.028	0.031	0.030	1.121	1.585	0.657
Knowledge storage	0.032	0.032	0.024	0.043	0.030	0.021	0.009	0.019	0.021	0.030	0.023	0.021	0.021	0.023	0.022	0.023	0.022	0.023	0.020	0.025	0.483	1.000	−0.033
Virtual team work	0.029	0.027	0.033	0.038	0.025	0.022	0.028	0.007	0.024	0.028	0.023	0.025	0.021	0.023	0.023	0.022	0.018	0.021	0.024	0.019	0.480	0.919	0.042
Knowledge portal…	0.019	0.022	0.028	0.038	0.023	0.024	0.020	0.021	0.008	0.034	0.024	0.022	0.020	0.020	0.022	0.023	0.022	0.024	0.021	0.022	0.456	0.939	−0.028
Exchange meetings…	0.018	0.018	0.022	0.034	0.017	0.018	0.022	0.020	0.026	0.014	0.025	0.021	0.020	0.007	0.023	0.020	0.020	0.018	0.019	0.020	0.403	1.507	−0.701
Work flow management	0.018	0.022	0.023	0.038	0.021	0.021	0.021	0.018	0.027	0.037	0.007	0.022	0.021	0.020	0.021	0.021	0.020	0.020	0.018	0.022	0.438	0.919	−0.043
Categorisation of Knowledge	0.022	0.024	0.026	0.035	0.019	0.019	0.021	0.019	0.020	0.039	0.021	0.007	0.021	0.022	0.021	0.019	0.018	0.023	0.018	0.020	0.435	0.911	−0.041
Trainer, Help of colleagues	0.045	0.042	0.042	0.706	0.040	0.038	0.039	0.035	0.039	0.052	0.037	0.043	0.024	0.038	0.043	0.031	0.037	0.038	0.041	0.030	1.438	1.907	0.968
Working associations communities	0.027	0.029	0.026	0.036	0.020	0.019	0.024	0.020	0.024	0.029	0.026	0.021	0.026	0.007	0.019	0.019	0.023	0.023	0.021	0.021	0.460	0.916	0.003
E-learning	0.029	0.027	0.027	0.043	0.023	0.023	0.028	0.024	0.021	0.032	0.021	0.025	0.024	0.024	0.008	0.022	0.021	0.023	0.023	0.022	0.491	0.977	0.006
Document management system	0.019	0.019	0.025	0.038	0.024	0.022	0.025	0.024	0.030	0.035	0.030	0.022	0.022	0.021	0.023	0.007	0.020	0.019	0.021	0.022	0.468	0.913	0.024
Expertise systems	0.026	0.026	0.021	0.039	0.023	0.022	0.025	0.019	0.023	0.032	0.021	0.020	0.024	0.027	0.026	0.022	0.007	0.024	0.022	0.021	0.471	0.915	0.027
Decision support system	0.027	0.033	0.027	0.044	0.026	0.031	0.030	0.022	0.021	0.036	0.023	0.020	0.023	0.027	0.017	0.021	0.024	0.008	0.022	0.025	0.507	0.963	0.051
Recommender systems	0.025	0.028	0.026	0.040	0.027	0.020	0.021	0.018	0.023	0.027	0.022	0.021	0.022	0.020	0.027	0.029	0.024	0.025	0.007	0.020	0.473	0.928	0.017
Knowledge maps	0.018	0.009	0.025	0.034	0.023	0.019	0.020	0.023	0.023	0.034	0.028	0.022	0.019	0.019	0.023	0.024	0.019	0.019	0.020	0.006	0.428	0.858	−0.002
c	0.507	0.527	0.535	1.466	0.496	0.464	0.517	0.438	0.483	1.104	0.481	0.476	0.469	0.456	0.486	0.444	0.444	0.456	0.456	0.430			

Table A10. Unweighted super matrix of knowledge management tools.

	Knowledge bases	Knowledge cafe	Knowledge trainer	organisational knowledge portal	Personal knowledge management	Skill mining	categorisation of knowledge	Exchange meeting ..	Knowledge portal	Knowledge warehouse	Trainer, help, …	Virtual team work	Work flow management	Decision support system	Document management system	E-learning	Expertise system	Knowledge maps	Recommender system	Working association
Knowledge bases	0.00	0.00	0.06938	0.09194	0.00	0.33450	0.00	0.00	0.00	0.00	0.26424	0.08543	0.00	0.26424	0.05193	0.37490	0.44726	0.00	0.30880	0.26424
Knowledge cafe	0.00	0.00	0.40304	0.39355	0.00	0.08459	0.00	0.00	0.00	0.00	0.08476	0.19307	0.00	0.08476	0.09977	0.25086	0.24636	0.00	0.23352	0.08476
Knowledge trainer	0.00	0.00	0.00000	0.23293	0.00	0.14880	0.00	0.00	0.00	0.00	0.15851	0.44585	0.00	0.15851	0.24291	0.10536	0.14086	0.00	0.18340	0.15851
organisational knowledge portal	0.00	0.00	0.07567	0.00000	0.00	0.31450	0.00	0.00	0.00	0.00	0.34062	0.19018	0.00	0.34062	0.20496	0.13564	0.06865	0.00	0.09995	0.34062
Personal knowledge management	0.00	0.00	0.17665	0.10465	0.00	0.11760	0.00	0.00	0.00	0.00	0.09437	0.04901	0.00	0.09437	0.16614	0.06453	0.03361	0.00	0.09705	0.09437
Skill mining	0.00	0.00	0.27526	0.17693	0.00	0.00000	0.00	0.00	0.00	0.00	0.05750	0.03646	0.00	0.05750	0.23428	0.06871	0.06326	0.00	0.07728	0.05750
Categorisation of Knowledge	0.00	0.00	0.35244	0.24334	0.00	0.32890	0.00	0.00	0.00	0.00	0.33254	0.09865	0.00	0.09883	0.10233	0.29961	0.33220	0.00	0.10556	0.35883
Exchange meeting ..	0.00	0.00	0.18296	0.08904	0.00	0.19882	0.00	0.00	0.00	0.00	0.05517	0.36486	0.00	0.20400	0.03710	0.19087	0.19087	0.00	0.03642	0.11156
Knowledge portal	0.00	0.00	0.22253	0.15831	0.00	0.08468	0.00	0.00	0.00	0.00	0.25714	0.17478	0.00	0.30811	0.05616	0.08316	0.14197	0.00	0.05679	0.21402
Knowledge warehouse	0.00	0.00	0.11185	0.30673	0.00	0.12436	0.00	0.00	0.00	0.00	0.12878	0.26491	0.00	0.24008	0.25134	0.15464	0.22503	0.00	0.26710	0.03750
Trainer, help, …	0.00	0.00	0.03501	0.09706	0.00	0.17534	0.00	0.00	0.00	0.00	0.00000	0.04142	0.00	0.06167	0.13961	0.19272	0.05586	0.00	0.13034	0.07898
Virtual team work	0.00	0.00	0.05023	0.05524	0.00	0.05000	0.00	0.00	0.00	0.00	0.10531	0.00000	0.00	0.03874	0.20454	0.04202	0.03475	0.00	0.19354	0.04098
Work flow management	0.00	0.00	0.04498	0.05028	0.00	0.03789	0.00	0.00	0.00	0.00	0.12106	0.05539	0.00	0.04857	0.20893	0.03699	0.04631	0.00	0.21025	0.15813
Decision Support system	0.00	0.00	0.29961	0.28766	0.00	0.31532	0.00	0.00	0.00	0.00	0.25943	0.05281	0.00	0.00000	0.23667	0.26413	0.25105	0.00	0.28713	0.13607
Document management system	0.00	0.00	0.17136	0.21166	0.00	0.23747	0.00	0.00	0.00	0.00	0.12779	0.05436	0.00	0.25596	0.00000	0.08474	0.14273	0.00	0.24193	0.08095
E-learning	0.00	0.00	0.17001	0.09856	0.00	0.14996	0.00	0.00	0.00	0.00	0.06055	0.33834	0.00	0.13843	0.09561	0.00000	0.07997	0.00	0.13790	0.15547
Expertise system	0.00	0.00	0.11762	0.10496	0.00	0.10605	0.00	0.00	0.00	0.00	0.30659	0.07214	0.00	0.13888	0.17942	0.15844	0.00000	0.00	0.15673	0.38007
Knowledge maps	0.00	0.00	0.14205	0.11627	0.00	0.07787	0.00	0.00	0.00	0.00	0.13507	0.13535	0.00	0.31216	0.34198	0.34064	0.32199	0.00	0.10089	0.09198
Recommender system	0.00	0.00	0.05380	0.12758	0.00	0.05422	0.00	0.00	0.00	0.00	0.07084	0.20787	0.00	0.08993	0.09209	0.09490	0.12430	0.00	0.00000	0.15547
Working association	0.00	0.00	0.04555	0.05331	0.00	0.05911	0.00	0.00	0.00	0.00	0.03973	0.13913	0.00	0.06464	0.05423	0.05715	0.07997	0.00	0.07543	0.00000

Table A11. Weighted supermatrix of knowledge management tools.

	Knowledge bases	Knowledge cafe	Knowledge trainer	organisational knowledge portal	Personal knowledge management	Skill mining	categorisation of knowledge	Exchange meeting ..	Knowledge portal	Knowledge warehouse	Trainer, help, …	Virtual team work	Work flow management	Decision support system	Document management system	E-learning	Expertise system	Knowledge maps	Recommender system	Working association
Knowledge bases	0.00	0.00	0.01337	0.01772	0.00	0.06447	0.00	0.00	0.00	0.00	0.16871	0.05455	0.00	0.07305	0.01436	0.10365	0.12365	0.00	0.08537	0.07305
Knowledge cafe	0.00	0.00	0.07768	0.07585	0.00	0.01630	0.00	0.00	0.00	0.00	0.05412	0.12327	0.00	0.02343	0.02758	0.06936	0.06811	0.00	0.06456	0.02343
Knowledge trainer	0.00	0.00	0.00000	0.04489	0.00	0.02868	0.00	0.00	0.00	0.00	0.10120	0.28466	0.00	0.04382	0.06716	0.02913	0.03894	0.00	0.05071	0.04382
organisational knowledge portal	0.00	0.00	0.01458	0.00000	0.00	0.06061	0.00	0.00	0.00	0.00	0.21747	0.12142	0.00	0.09417	0.05667	0.03750	0.01898	0.00	0.02763	0.09417
Personal knowledge management	0.00	0.00	0.03404	0.02017	0.00	0.02266	0.00	0.00	0.00	0.00	0.06025	0.03129	0.00	0.02609	0.04593	0.01784	0.00929	0.00	0.02683	0.02609
Skill mining	0.00	0.00	0.05305	0.03410	0.00	0.00000	0.00	0.00	0.00	0.00	0.03671	0.02328	0.00	0.01590	0.06477	0.01900	0.01749	0.00	0.02136	0.01590
Categorisation of Knowledge	0.00	0.00	0.02954	0.02040	0.00	0.02757	0.00	0.00	0.00	0.00	0.02391	0.00709	0.00	0.00698	0.00723	0.02117	0.02347	0.00	0.00746	0.02536
Exchange meeting ..	0.00	0.00	0.01534	0.00746	0.00	0.01667	0.00	0.00	0.00	0.00	0.00397	0.02624	0.00	0.01442	0.00262	0.01349	0.01158	0.00	0.00257	0.00788
Knowledge portal	0.00	0.00	0.01865	0.01327	0.00	0.00710	0.00	0.00	0.00	0.00	0.01849	0.01257	0.00	0.02177	0.00397	0.00588	0.01003	0.00	0.00401	0.01512
Knowledge warehouse	0.00	0.00	0.00937	0.02571	0.00	0.01042	0.00	0.00	0.00	0.00	0.00926	0.01905	0.00	0.01696	0.01776	0.01093	0.01590	0.00	0.01887	0.00265
Trainer, help, …	0.00	0.00	0.00294	0.00814	0.00	0.01470	0.00	0.00	0.00	0.00	0.00000	0.00298	0.00	0.00436	0.00987	0.01362	0.00395	0.00	0.00921	0.00558
Virtual team work	0.00	0.00	0.00421	0.00463	0.00	0.00419	0.00	0.00	0.00	0.00	0.00757	0.00000	0.00	0.00274	0.01445	0.00297	0.00246	0.00	0.01368	0.00290
Work flow management	0.00	0.00	0.00377	0.00422	0.00	0.00318	0.00	0.00	0.00	0.00	0.00871	0.00398	0.00	0.00343	0.01476	0.00261	0.00327	0.00	0.01486	0.01117
Decision Support system	0.00	0.00	0.21676	0.20811	0.00	0.22812	0.00	0.00	0.00	0.00	0.07514	0.01529	0.00	0.00000	0.15452	0.17244	0.16390	0.00	0.18746	0.08883
Document management system	0.00	0.00	0.12397	0.15313	0.00	0.17180	0.00	0.00	0.00	0.00	0.03701	0.01574	0.00	0.16711	0.00000	0.05532	0.09318	0.00	0.15795	0.05285
E-learning	0.00	0.00	0.12300	0.07130	0.00	0.10849	0.00	0.00	0.00	0.00	0.01754	0.09799	0.00	0.09038	0.06242	0.00000	0.05221	0.00	0.09003	0.10150
Expertise system	0.00	0.00	0.08509	0.07593	0.00	0.07673	0.00	0.00	0.00	0.00	0.08880	0.02089	0.00	0.09067	0.11714	0.10344	0.00000	0.00	0.10232	0.24814
Knowledge maps	0.00	0.00	0.10277	0.08411	0.00	0.05633	0.00	0.00	0.00	0.00	0.03912	0.03920	0.00	0.20380	0.22327	0.22239	0.21022	0.00	0.06587	0.06005
Recommender system	0.00	0.00	0.03892	0.09230	0.00	0.03923	0.00	0.00	0.00	0.00	0.02052	0.06021	0.00	0.05871	0.06012	0.06195	0.08115	0.00	0.00000	0.10150
Working association	0.00	0.00	0.03295	0.03857	0.00	0.04276	0.00	0.00	0.00	0.00	0.01151	0.04030	0.00	0.04220	0.03541	0.03731	0.05221	0.00	0.04924	0.00000

Table A12. Limited matrix of knowledge management tools.

	Knowledge bases	Knowledge cafe	Knowledge trainer	organisational knowledge portal	Personal knowledge management	Skill mining	categorisation of knowledge	Exchange meeting ..	Knowledge portal	Knowledge warehouse	Trainer, help, …	Virtual team work	Work flow management	Decision support system	Document management system	E-learning	Expertise system	Knowledge maps	Recommender system	Working association
Knowledge bases	0.00	0.00	0.06729	0.06729	0.00	0.06729	0.00	0.00	0.00	0.00	0.06729	0.06729	0.00	0.06729	0.06729	0.06729	0.06729	0.00	0.06729	0.06729
Knowledge cafe	0.00	0.00	0.04860	0.04860	0.00	0.04860	0.00	0.00	0.00	0.00	0.04860	0.04860	0.00	0.04860	0.04860	0.04860	0.04860	0.00	0.04860	0.04860
Knowledge trainer	0.00	0.00	0.04510	0.04510	0.00	0.04510	0.00	0.00	0.00	0.00	0.04510	0.04510	0.00	0.04510	0.04510	0.04510	0.04510	0.00	0.04510	0.04510
organisational knowledge portal	0.00	0.00	0.05165	0.05165	0.00	0.05165	0.00	0.00	0.00	0.00	0.05165	0.05165	0.00	0.05165	0.05165	0.05165	0.05165	0.00	0.05165	0.05165
Personal knowledge management	0.00	0.00	0.02639	0.02639	0.00	0.02639	0.00	0.00	0.00	0.00	0.02639	0.02639	0.00	0.02639	0.02639	0.02639	0.02639	0.00	0.02639	0.02639
Skill mining	0.00	0.00	0.02855	0.02855	0.00	0.02855	0.00	0.00	0.00	0.00	0.02855	0.02855	0.00	0.02855	0.02855	0.02855	0.02855	0.00	0.02855	0.02855
Categorisation of Knowledge	0.00	0.00	0.01596	0.01596	0.00	0.01596	0.00	0.00	0.00	0.00	0.01596	0.01596	0.00	0.01596	0.01596	0.01596	0.01596	0.00	0.01596	0.01596
Exchange meeting ..	0.00	0.00	0.01009	0.01009	0.00	0.01009	0.00	0.00	0.00	0.00	0.01009	0.01009	0.00	0.01009	0.01009	0.01009	0.01009	0.00	0.01009	0.01009
Knowledge portal	0.00	0.00	0.01168	0.01168	0.00	0.01168	0.00	0.00	0.00	0.00	0.01168	0.01168	0.00	0.01168	0.01168	0.01168	0.01168	0.00	0.01168	0.01168
Knowledge warehouse	0.00	0.00	0.01538	0.01538	0.00	0.01538	0.00	0.00	0.00	0.00	0.01538	0.01538	0.00	0.01538	0.01538	0.01538	0.01538	0.00	0.01538	0.01538
Trainer, help, …	0.00	0.00	0.00736	0.00736	0.00	0.00736	0.00	0.00	0.00	0.00	0.00736	0.00736	0.00	0.00736	0.00736	0.00736	0.00736	0.00	0.00736	0.00736
Virtual team work	0.00	0.00	0.00600	0.00600	0.00	0.00600	0.00	0.00	0.00	0.00	0.00600	0.00600	0.00	0.00600	0.00600	0.00600	0.00600	0.00	0.00600	0.00600
Work flow management	0.00	0.00	0.00682	0.00682	0.00	0.00682	0.00	0.00	0.00	0.00	0.00682	0.00682	0.00	0.00682	0.00682	0.00682	0.00682	0.00	0.00682	0.00682
Decision support system	0.00	0.00	0.13421	0.13421	0.00	0.13421	0.00	0.00	0.00	0.00	0.13421	0.13421	0.00	0.13421	0.13421	0.13421	0.13421	0.00	0.13421	0.13421
Document management system	0.00	0.00	0.10233	0.10233	0.00	0.10233	0.00	0.00	0.00	0.00	0.10233	0.10233	0.00	0.10233	0.10233	0.10233	0.10233	0.00	0.10233	0.10233
E-learning	0.00	0.00	0.07169	0.07169	0.00	0.07169	0.00	0.00	0.00	0.00	0.07169	0.07169	0.00	0.07169	0.07169	0.07169	0.07169	0.00	0.07169	0.07169
Expertise system	0.00	0.00	0.09117	0.09117	0.00	0.09117	0.00	0.00	0.00	0.00	0.09117	0.09117	0.00	0.09117	0.09117	0.09117	0.09117	0.00	0.09117	0.09117
Knowledge maps	0.00	0.00	0.16132	0.16132	0.00	0.16132	0.00	0.00	0.00	0.00	0.16132	0.16132	0.00	0.16132	0.16132	0.16132	0.16132	0.00	0.16132	0.16132
Recommender system	0.00	0.00	0.05964	0.05964	0.00	0.05964	0.00	0.00	0.00	0.00	0.05964	0.05964	0.00	0.05964	0.05964	0.05964	0.05964	0.00	0.05964	0.05964
Working association	0.00	0.00	0.03878	0.03878	0.00	0.03878	0.00	0.00	0.00	0.00	0.03878	0.03878	0.00	0.03878	0.03878	0.03878	0.03878	0.00	0.03878	0.03878

Table A13. Weights of knowledge management tools.

Knowledge management tools	Global weights	Local weights
Knowledge bases	0.06729	0.25149
Knowledge cafe	0.04860	0.18162
Knowledge trainer	0.04510	0.16855
organisational knowledge portal	0.05165	0.19302
Personal knowledge management	0.02639	0.09862
Skill mining	0.02855	0.10670
Categorisation of Knowledge	0.01596	0.21773
Exchange Meetings after the Completion of the Project	0.01009	0.13773
Knowledge portal	0.01168	0.15932
Knowledge warehouse	0.01538	0.20983
Trainer, Help of colleagues	0.00736	0.10048
Virtual team work	0.00600	0.08181
Work flow management	0.00682	0.09311
Decision Support system	0.13421	0.20362
Document management system	0.10233	0.15525
E-learning	0.07169	0.10876
Expertise system	0.09117	0.13831
Knowledge maps	0.16132	0.24474
Recommender system	0.05964	0.09049
Working association	0.03878	0.05884

Table A14. Weights and normalised matrix.

	Knowledge bases	Knowledge cafe	Knowledge trainer	organisational knowledge portal	Personal knowledge management	Skill mining	categorisation of knowledge	Exchange meeting ..	Knowledge portal	Knowledge warehouse	Trainer, help, …	Virtual team work	Work flow management	Decision support system	Document management system	E-learning	Expertise system	Knowledge maps	Recommender system	Working association
W_{ij}	0.0672	0.0486	0.0451	0.0516	0.0263	0.0285	0.0159	0.1	0.0116	0.0073	0.006	0.0068	0.134	0.1023	0.0716	0.0911	0.0911	0.1612	0.0596	0.0387
Knowledge bases	0	0.023	0.024	0.02	0.019	0.015	0.024	0.018	0.012	0.012	0.015	0.022	0.021	0.021	0.016	0.016	0.016	0.018	0.02	0.014
Knowledge cafe	0.019	0	0.02	0.019	0.018	0.017	0.023	0.015	0.017	0.013	0.014	0.02	0.022	0.023	0.019	0.015	0.022	0.019	0.018	0.015
Knowledge trainer	0.023	0.023	0	0.019	0.018	0.019	0.018	0.017	0.019	0.016	0.021	0.014	0.016	0.017	0.015	0.018	0.014	0.017	0.015	0.014
Org. knowledge portal	0.019	0.017	0.015	0	0.02	0.02	0.022	0.018	0.017	0.016	0.014	0.019	0.017	0.015	0.019	0.013	0.015	0.016	0.018	0.012
Personal KM	0.019	0.022	0.015	0.023	0	0.018	0.02	0.016	0.016	0.013	0.014	0.018	0.015	0.015	0.02	0.009	0.015	0.012	0.019	0.015
Skill mining	0.014	0.024	0.025	0.015	0.024	0	0.018	0.013	0.015	0.47	0.014	0.015	0.019	0.018	0.02	0.018	0.013	0.013	0.016	0.015
Categorisation of Knowledge	0.024	0.025	0.015	0.022	0.023	0.014	0	0.012	0.013	0.013	0.015	0.013	0.013	0.016	0.014	0.016	0.016	0.016	0.013	0.018
Exchange meeting ..	0.021	0.018	0.025	0.016	0.017	0.015	0.02	0	0.016	0.012	0.015	0.019	0.013	0.016	0.016	0.015	0.011	0.014	0.017	0.012
Knowledge portal	0.012	0.014	0.02	0.017	0.016	0.017	0.012	0.014	0	0.018	0.017	0.015	0.013	0.013	0.015	0.017	0.015	0.017	0.014	0.016
Knowledge warehouse	0.011	0.011	0.015	0.014	0.01	0.012	0.016	0.014	0.021	0	0.019	0.016	0.014	0.001	0.017	0.014	0.014	0.013	0.013	0.014
Trainer, help, …	0.011	0.015	0.015	0.017	0.015	0.014	0.014	0.013	0.02	0.022	0	0.015	0.014	0.013	0.014	0.015	0.014	0.013	0.012	0.016
Virtual team work	0.015	0.016	0.019	0.015	0.012	0.012	0.014	0.013	0.013	0.024	0.014	0	0.014	0.016	0.014	0.013	0.012	0.017	0.011	0.014
Work flow management	0.021	0.019	0.018	0.687	0.014	0.013	0.012	0.013	0.016	0.013	0.016	0.018	0	0.016	0.018	0.011	0.016	0.016	0.018	0.011
Decision Support system	0.019	0.021	0.018	0.011	0.013	0.012	0.016	0.013	0.017	0.014	0.02	0.014	0.019	0	0.012	0.012	0.016	0.016	0.014	0.014
Document management system	0.021	0.018	0.018	0.019	0.015	0.016	0.021	0.017	0.014	0.014	0.013	0.018	0.016	0.017	0	0.015	0.014	0.016	0.016	0.015
E-learning	0.012	0.011	0.017	0.016	0.016	0.015	0.017	0.017	0.023	0.018	0.023	0.015	0.015	0.015	0.016	0	0.013	0.013	0.015	0.015
Expertise system	0.018	0.018	0.013	0.015	0.015	0.015	0.018	0.012	0.016	0.015	0.013	0.013	0.018	0.021	0.019	0.015	0	0.017	0.015	0.014
Knowledge maps	0.02	0.024	0.018	0.022	0.018	0.023	0.022	0.016	0.013	0.015	0.015	0.012	0.015	0.02	0.009	0.013	0.017	0	0.014	0.018
Recommender system	0.017	0.02	0.018	0.017	0.019	0.013	0.014	0.011	0.015	0.011	0.014	0.013	0.015	0.014	0.02	0.022	0.018	0.019	0	0.013
Working association	0.012	0.001	0.019	0.015	0.016	0.012	0.014	0.017	0.016	0.019	0.021	0.016	0.012	0.013	0.016	0.018	0.013	0.013	0.015	0

Table A15. Aspired or tolerable level matrix.

	Knowledge bases	Knowledge cafe	Knowledge trainer	organisational knowledge portal	Personal knowledge management	Skill mining	categorisation of knowledge	Exchange meeting ..	Knowledge portal	Knowledge warehouse	Trainer, help, …	Virtual team work	Work flow management	Decision support system	Document management system	E-learning	Expertise system	Knowledge maps	Recommender system	Working association
W_j	0.0672	0.0486	0.0451	0.0516	0.0263	0.0285	0.0159	0.1	0.0116	0.0073	0.006	0.0068	0.134	0.1023	0.0716	0.0911	0.0911	0.1612	0.0596	0.0387
Knowledge bases	0.0000	0.0011	0.0011	0.0010	0.0005	0.0004	0.0004	0.0018	0.0001	0.0001	0.0001	0.0001	0.0028	0.0021	0.0011	0.0015	0.0015	0.0029	0.0012	0.0005
Knowledge cafe	0.0013	0.0000	0.0009	0.0010	0.0005	0.0005	0.0004	0.0015	0.0002	0.0001	0.0001	0.0001	0.0029	0.0024	0.0014	0.0014	0.0020	0.0031	0.0011	0.0006
Knowledge trainer	0.0015	0.0011	0.0000	0.0010	0.0005	0.0005	0.0003	0.0017	0.0002	0.0001	0.0001	0.0001	0.0021	0.0017	0.0011	0.0016	0.0013	0.0027	0.0009	0.0005
Organisational knowledge portal	0.0013	0.0008	0.0007	0.0000	0.0005	0.0006	0.0003	0.0018	0.0002	0.0001	0.0001	0.0001	0.0023	0.0015	0.0014	0.0012	0.0014	0.0026	0.0011	0.0005
Personal knowledge management	0.0013	0.0011	0.0007	0.0012	0.0000	0.0005	0.0003	0.0016	0.0002	0.0001	0.0001	0.0001	0.0020	0.0015	0.0014	0.0008	0.0014	0.0019	0.0011	0.0006
Skill mining	0.0009	0.0012	0.0011	0.0008	0.0006	0.0000	0.0003	0.0013	0.0002	0.0034	0.0001	0.0001	0.0025	0.0018	0.0014	0.0016	0.0012	0.0021	0.0010	0.0006
Categorisation of knowledge	0.0016	0.0012	0.0007	0.0011	0.0006	0.0004	0.0000	0.0012	0.0002	0.0001	0.0001	0.0001	0.0017	0.0016	0.0010	0.0015	0.0015	0.0026	0.0008	0.0007
Exchange meeting ..	0.0014	0.0009	0.0011	0.0008	0.0004	0.0004	0.0003	0.0000	0.0002	0.0001	0.0001	0.0001	0.0017	0.0016	0.0011	0.0014	0.0010	0.0023	0.0010	0.0005
Knowledge portal	0.0008	0.0007	0.0009	0.0009	0.0004	0.0005	0.0002	0.0014	0.0000	0.0001	0.0001	0.0001	0.0017	0.0013	0.0011	0.0015	0.0014	0.0027	0.0008	0.0006
Knowledge warehouse	0.0007	0.0005	0.0007	0.0007	0.0003	0.0003	0.0003	0.0014	0.0002	0.0000	0.0001	0.0001	0.0019	0.0001	0.0012	0.0013	0.0013	0.0021	0.0008	0.0005
Trainer, help, …	0.0007	0.0007	0.0007	0.0009	0.0004	0.0004	0.0002	0.0013	0.0002	0.0002	0.0000	0.0001	0.0019	0.0013	0.0010	0.0014	0.0013	0.0021	0.0007	0.0006
Virtual team work	0.0010	0.0008	0.0009	0.0008	0.0003	0.0003	0.0002	0.0013	0.0002	0.0002	0.0001	0.0000	0.0019	0.0016	0.0010	0.0012	0.0011	0.0027	0.0007	0.0005
Work flow management	0.0014	0.0009	0.0008	0.0354	0.0004	0.0004	0.0002	0.0013	0.0002	0.0001	0.0001	0.0001	0.0000	0.0016	0.0013	0.0010	0.0015	0.0026	0.0011	0.0004
Decision Support system	0.0013	0.0010	0.0008	0.0006	0.0003	0.0003	0.0003	0.0013	0.0002	0.0001	0.0001	0.0001	0.0025	0.0000	0.0009	0.0011	0.0015	0.0026	0.0008	0.0005
Document management system	0.0014	0.0009	0.0008	0.0010	0.0004	0.0005	0.0003	0.0017	0.0002	0.0001	0.0001	0.0001	0.0021	0.0017	0.0000	0.0014	0.0013	0.0026	0.0010	0.0006
E-learning	0.0008	0.0005	0.0008	0.0008	0.0004	0.0004	0.0003	0.0017	0.0003	0.0001	0.0001	0.0001	0.0020	0.0015	0.0011	0.0000	0.0012	0.0021	0.0009	0.0006
Expertise system	0.0012	0.0009	0.0006	0.0008	0.0004	0.0004	0.0003	0.0012	0.0002	0.0001	0.0001	0.0001	0.0024	0.0021	0.0014	0.0014	0.0000	0.0027	0.0009	0.0005
Knowledge maps	0.0013	0.0012	0.0008	0.0011	0.0005	0.0007	0.0003	0.0016	0.0002	0.0001	0.0001	0.0001	0.0020	0.0020	0.0006	0.0012	0.0015	0.0000	0.0008	0.0007
Recommender system	0.0011	0.0010	0.0008	0.0009	0.0005	0.0004	0.0002	0.0011	0.0002	0.0001	0.0001	0.0001	0.0020	0.0014	0.0014	0.0020	0.0016	0.0031	0.0000	0.0005
Working association	0.0008	0.0000	0.0009	0.0008	0.0004	0.0003	0.0002	0.0017	0.0002	0.0001	0.0001	0.0001	0.0016	0.0013	0.0011	0.0016	0.0012	0.0021	0.0009	0.0000
$F+$ (max)	0.0016	0.0012	0.0011	0.0354	0.0006	0.0007	0.0004	0.0018	0.0003	0.0034	0.0001	0.0001	0.0029	0.0024	0.0014	0.0020	0.0020	0.0031	0.0012	0.0007
$F-$ (min)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$F+$ (max)–$F-$ (min)	0.0016	0.0012	0.0011	0.0354	0.0006	0.0007	0.0004	0.0018	0.0003	0.0034	0.0001	0.0001	0.0029	0.0024	0.0014	0.0020	0.0020	0.0031	0.0012	0.0007

Table A16. The matrix by $w_j\left(\left|f_j^* - f_{kj}\right|\right) / \left(\left|f_j^* - f_{kj}\right|\right)$.

	Knowledge bases	Knowledge cafe	Knowledge trainer	organisational knowledge portal	Personal knowledge management	Skill mining	categorisation of knowledge	Exchange meeting ..	Knowledge portal	Knowledge warehouse	Trainer, help, …	Virtual team work	Work flow management	Decision support system	Document management system	E-learning	Expertise system	Knowledge maps	Recommender system	Working association
W_j	0.0672	0.0486	0.0451	0.0516	0.0263	0.0285	0.0159	0.1	0.0116	0.0073	0.006	0.0068	0.134	0.1023	0.0716	0.0911	0.0911	0.1612	0.0596	0.0387
Knowledge bases	0.0016	0.0001	0.0000	0.0344	0.0001	0.0002	0.0000	0.0000	0.0001	0.0033	0.0000	0.0000	0.0001	0.0002	0.0003	0.0005	0.0005	0.0002	0.0000	0.0002
Knowledge cafe	0.0003	0.0012	0.0002	0.0345	0.0002	0.0002	0.0000	0.0003	0.0001	0.0033	0.0001	0.0000	0.0000	0.0000	0.0001	0.0006	0.0000	0.0000	0.0001	0.0001
Knowledge trainer	0.0001	0.0001	0.0011	0.0345	0.0002	0.0001	0.0001	0.0001	0.0000	0.0033	0.0000	0.0001	0.0008	0.0006	0.0004	0.0004	0.0007	0.0003	0.0003	0.0002
Organisational knowledge portal	0.0003	0.0004	0.0005	0.0354	0.0001	0.0001	0.0000	0.0000	0.0001	0.0033	0.0001	0.0000	0.0007	0.0008	0.0001	0.0008	0.0006	0.0005	0.0001	0.0002
Personal KM	0.0003	0.0001	0.0005	0.0343	0.0006	0.0001	0.0001	0.0002	0.0001	0.0033	0.0001	0.0000	0.0009	0.0008	0.0000	0.0012	0.0006	0.0011	0.0001	0.0001
Skill mining	0.0007	0.0000	0.0000	0.0347	0.0000	0.0007	0.0001	0.0005	0.0001	0.0000	0.0001	0.0000	0.0004	0.0005	0.0000	0.0004	0.0008	0.0010	0.0002	0.0001
Categorisation of Knowledge	0.0000	0.0000	0.0005	0.0343	0.0000	0.0003	0.0004	0.0006	0.0001	0.0033	0.0000	0.0001	0.0012	0.0007	0.0004	0.0005	0.0005	0.0005	0.0004	0.0000
Exchange meeting	0.0002	0.0003	0.0000	0.0346	0.0002	0.0002	0.0001	0.0018	0.0001	0.0033	0.0000	0.0000	0.0012	0.0007	0.0003	0.0006	0.0010	0.0008	0.0002	0.0002
Knowledge portal	0.0008	0.0005	0.0002	0.0346	0.0002	0.0002	0.0002	0.0004	0.0003	0.0033	0.0000	0.0000	0.0012	0.0010	0.0004	0.0005	0.0006	0.0003	0.0004	0.0001
Knowledge warehouse	0.0009	0.0007	0.0005	0.0347	0.0004	0.0003	0.0001	0.0004	0.0000	0.0034	0.0000	0.0000	0.0011	0.0023	0.0002	0.0007	0.0007	0.0010	0.0004	0.0002
Trainer, help, …	0.0009	0.0005	0.0005	0.0346	0.0002	0.0003	0.0002	0.0005	0.0000	0.0033	0.0001	0.0000	0.0011	0.0010	0.0004	0.0006	0.0007	0.0010	0.0005	0.0001
Virtual team work	0.0006	0.0004	0.0003	0.0347	0.0003	0.0003	0.0002	0.0005	0.0001	0.0033	0.0001	0.0001	0.0011	0.0007	0.0004	0.0008	0.0009	0.0003	0.0005	0.0002
Work flow management	0.0002	0.0003	0.0003	0.0000	0.0003	0.0003	0.0002	0.0005	0.0001	0.0033	0.0000	0.0000	0.0029	0.0007	0.0001	0.0010	0.0005	0.0005	0.0001	0.0003
Decision Support system	0.0003	0.0002	0.0003	0.0349	0.0003	0.0003	0.0001	0.0005	0.0001	0.0033	0.0000	0.0001	0.0004	0.0024	0.0006	0.0009	0.0005	0.0005	0.0004	0.0002
Document management system	0.0002	0.0003	0.0003	0.0345	0.0002	0.0002	0.0000	0.0001	0.0001	0.0033	0.0001	0.0000	0.0008	0.0006	0.0014	0.0006	0.0007	0.0005	0.0002	0.0001
E-learning	0.0008	0.0007	0.0004	0.0346	0.0002	0.0002	0.0001	0.0001	0.0000	0.0033	0.0000	0.0000	0.0009	0.0008	0.0003	0.0020	0.0008	0.0010	0.0003	0.0001
Expertise system	0.0004	0.0003	0.0005	0.0347	0.0002	0.0002	0.0001	0.0006	0.0001	0.0033	0.0001	0.0001	0.0005	0.0002	0.0001	0.0006	0.0020	0.0003	0.0003	0.0002
Knowledge maps	0.0003	0.0000	0.0003	0.0343	0.0002	0.0000	0.0000	0.0002	0.0001	0.0033	0.0000	0.0001	0.0009	0.0003	0.0008	0.0008	0.0005	0.0031	0.0004	0.0000
Recommender system	0.0005	0.0002	0.0003	0.0346	0.0001	0.0003	0.0002	0.0007	0.0001	0.0034	0.0001	0.0001	0.0009	0.0009	0.0000	0.0000	0.0004	0.0000	0.0012	0.0002
Working association	0.0008	0.0012	0.0003	0.0347	0.0002	0.0003	0.0002	0.0001	0.0001	0.0033	0.0000	0.0000	0.0013	0.0010	0.0003	0.0004	0.0008	0.0010	0.0003	0.0007
$F+$ (max)	0.0016	0.0001	0.0000	0.0344	0.0001	0.0002	0.0000	0.0000	0.0001	0.0033	0.0000	0.0000	0.0001	0.0002	0.0003	0.0005	0.0005	0.0002	0.0000	0.0002
$F-$ (Min)	0.0003	0.0012	0.0002	0.0345	0.0002	0.0002	0.0000	0.0003	0.0001	0.0033	0.0001	0.0000	0.0000	0.0000	0.0001	0.0006	0.0000	0.0000	0.0001	0.0001
$F+$ (max)–$F-$ (min)	0.0001	0.0001	0.0011	0.0345	0.0002	0.0001	0.0001	0.0001	0.0000	0.0033	0.0000	0.0001	0.0008	0.0006	0.0004	0.0004	0.0007	0.0003	0.0003	0.0002

Table A17. Group utility and maximal regret matrix.

	Knowledge bases	Knowledge cafe	Knowledge trainer	organisational knowledge portal	Personal knowledge management	Skill mining	categorisation of knowledge	Exchange meeting ..	Knowledge portal	Knowledge warehouse	Trainer, help, …	Virtual team work	Work flow management	Decision support system	Document management system	E-learning	Expertise system	Knowledge maps	Recommender system	Working association		
W_{ij}	0.0672	0.0486	0.0451	0.0516	0.0263	0.0285	0.0159	0.1	0.0116	0.0073	0.006	0.0068	0.134	0.1023	0.0716	0.0911	0.0911	0.1612	0.0596	0.0387	S_j	R_j
Knowledge bases	2.8000	1.9440	1.8040	0.0751	1.0958	1.2391	0.6625	5.5556	0.5043	0.0155	0.2609	0.3091	6.0909	4.4478	3.5800	4.1409	4.1409	8.4842	2.9800	2.1500	52.2807326	8.4842105
Knowledge cafe	0.0672	0.0039	0.0018	0.0501	0.0055	0.0099	0.0000	0.0000	0.0055	0.0071	0.0021	0.0000	0.0061	0.0089	0.0143	0.0248	0.0248	0.0085	0.0000	0.0086	0.24921211	0.0672
Knowledge trainer	0.0140	0.0486	0.0090	0.0502	0.0066	0.0074	0.0007	0.0167	0.0030	0.0071	0.0023	0.0006	0.0000	0.0000	0.0036	0.0290	0.0000	0.0000	0.0060	0.0065	0.21119842	0.0501729
organisational knowledge portal	0.0028	0.0039	0.0451	0.0502	0.0066	0.0050	0.0040	0.0056	0.0020	0.0071	0.0005	0.0025	0.0365	0.0267	0.0179	0.0166	0.0331	0.0170	0.0149	0.0086	0.30637809	0.0501729
Personal KM	0.0140	0.0156	0.0180	0.0516	0.0044	0.0037	0.0013	0.0000	0.0030	0.0071	0.0023	0.0009	0.0305	0.0356	0.0036	0.0373	0.0290	0.0255	0.0060	0.0129	0.30215473	0.0516
Skill mining	0.0140	0.0058	0.0180	0.0499	0.0263	0.0062	0.0027	0.0111	0.0035	0.0071	0.0023	0.0012	0.0426	0.0356	0.0000	0.0538	0.0290	0.0594	0.0030	0.0065	0.37807059	0.0593895
Categorisation of Knowledge	0.0280	0.0019	0.0000	0.0505	0.0000	0.0285	0.0040	0.0278	0.0040	0.0000	0.0023	0.0022	0.0183	0.0222	0.0000	0.0166	0.0373	0.0509	0.0119	0.0065	0.31283532	0.0509053
Exchange meeting ..	0.0000	0.0000	0.0180	0.0499	0.0011	0.0112	0.0159	0.0333	0.0050	0.0071	0.0021	0.0028	0.0548	0.0311	0.0215	0.0248	0.0248	0.0255	0.0209	0.0000	0.34991578	0.0548182
Knowledge portal	0.0084	0.0136	0.0000	0.0504	0.0077	0.0099	0.0027	0.1000	0.0035	0.0071	0.0021	0.0009	0.0548	0.0311	0.0143	0.0290	0.0456	0.0424	0.0089	0.0129	0.44536879	0.1
Knowledge warehouse	0.0336	0.0214	0.0090	0.0503	0.0088	0.0074	0.0080	0.0222	0.0116	0.0070	0.0016	0.0022	0.0548	0.0445	0.0179	0.0207	0.0290	0.0170	0.0179	0.0043	0.38908587	0.0548182
Trainer, help, …	0.0364	0.0272	0.0180	0.0505	0.0153	0.0136	0.0053	0.0222	0.0010	0.0073	0.0010	0.0019	0.0487	0.0979	0.0107	0.0331	0.0331	0.0509	0.0209	0.0086	0.50384477	0.0978522
Virtual team work	0.0364	0.0194	0.0180	0.0503	0.0099	0.0112	0.0066	0.0278	0.0015	0.0070	0.0060	0.0022	0.0487	0.0445	0.0215	0.0290	0.0331	0.0509	0.0238	0.0043	0.45210001	0.0509053
Work flow management	0.0252	0.0175	0.0108	0.0505	0.0132	0.0136	0.0066	0.0278	0.0050	0.0069	0.0023	0.0068	0.0487	0.0311	0.0215	0.0373	0.0414	0.0170	0.0268	0.0086	0.41870286	0.0504734
Decision Support system	0.0084	0.0117	0.0126	0.0000	0.0110	0.0124	0.0080	0.0278	0.0035	0.0071	0.0018	0.0012	0.1340	0.0311	0.0072	0.0456	0.0248	0.0255	0.0060	0.0151	0.39461325	0.134
Document management system	0.0140	0.0078	0.0126	0.0508	0.0121	0.0136	0.0053	0.0278	0.0030	0.0071	0.0008	0.0025	0.0183	0.1023	0.0286	0.0414	0.0248	0.0255	0.0179	0.0086	0.42470406	0.1023
E-learning	0.0084	0.0136	0.0126	0.0502	0.0099	0.0087	0.0020	0.0056	0.0045	0.0071	0.0026	0.0012	0.0365	0.0267	0.0716	0.0290	0.0331	0.0255	0.0119	0.0065	0.36712382	0.0716
Expertise system	0.0336	0.0272	0.0144	0.0504	0.0088	0.0099	0.0046	0.0056	0.0000	0.0070	0.0000	0.0022	0.0426	0.0356	0.0143	0.0911	0.0373	0.0509	0.0149	0.0065	0.4568655	0.0911
Knowledge maps	0.0168	0.0136	0.0216	0.0505	0.0099	0.0099	0.0040	0.0333	0.0035	0.0071	0.0026	0.0028	0.0244	0.0089	0.0036	0.0290	0.0911	0.0170	0.0149	0.0086	0.37299528	0.0911
Recommender system	0.0112	0.0019	0.0126	0.0499	0.0066	0.0000	0.0013	0.0111	0.0050	0.0071	0.0021	0.0031	0.0426	0.0133	0.0394	0.0373	0.0207	0.1612	0.0179	0.0000	0.44443164	0.1612
Working association	0.0196	0.0097	0.0126	0.0503	0.0055	0.0124	0.0066	0.0389	0.0040	0.0071	0.0023	0.0028	0.0426	0.0400	0.0000	0.0000	0.0166	0.0000	0.0596	0.0108	0.34152951	0.0596

S^+	52.2807	R^+	8.4842
S-	0.2112	R^-	0.0502
$S^+ - S^-$	52.0695	$R^+ - R^-$	8.4340

Table A18. Index value matrix.

	$S^j - S^+$	$S^+ - S^-$	$R^j - R^-$	$R^+ - R^-$	$S^j - S^+/S^+ - S^-$	$R^j - R^-/R^+ - R-$	$v^*(S^j - S^+/S^+ - S^-)$	$(1-v)^*(R^j - R^-/R^+ - R^-)$	$Q = v^*(S^j - S^+/S^+ - S^-) + (1-v)^*(R^j - R^-/R^+ - R^-)$	Priority
Knowledge bases	0.000000	52.069534	8.434038	8.434038	0.000000	1.000000	0.000000	0.500000	0.500000	1
Knowledge cafe	−52.031520	52.069534	0.017027	8.434038	−0.999270	0.002019	−0.499635	0.001009	−0.498626	16
Knowledge trainer	−52.069534	52.069534	0.000000	8.434038	−1.000000	0.000000	−0.500000	0.000000	−0.500000	20
organisational knowledge portal	−51.974355	52.069534	0.000000	8.434038	−0.998172	0.000000	−0.499086	0.000000	−0.499086	19
Personal knowledge management	−51.978578	52.069534	0.001427	8.434038	−0.998253	0.000169	−0.499127	0.000085	−0.499042	18
Skill mining	−51.902662	52.069534	0.009217	8.434038	−0.996795	0.001093	−0.498398	0.000546	−0.497851	11
Categorisation of Knowledge	−51.967897	52.069534	0.000732	8.434038	−0.998048	0.000087	−0.499024	0.000043	−0.498981	17
Exchange meeting ..	−51.930817	52.069534	0.004645	8.434038	−0.997336	0.000551	−0.498668	0.000275	−0.498393	15
Knowledge portal	−51.835364	52.069534	0.049827	8.434038	−0.995503	0.005908	−0.497751	0.002954	−0.494797	5
Knowledge warehouse	−51.891647	52.069534	0.004645	8.434038	−0.996584	0.000551	−0.498292	0.000275	−0.498016	13
Trainer, help, …	−51.776888	52.069534	0.047679	8.434038	−0.994380	0.005653	−0.497190	0.002827	−0.494363	4
Virtual team work	−51.828633	52.069534	0.000732	8.434038	−0.995373	0.000087	−0.497687	0.000043	−0.497643	10
Work flow management	−51.862030	52.069534	0.000300	8.434038	−0.996015	0.000036	−0.498007	0.000018	−0.497990	12
Decision support system	−51.886119	52.069534	0.083827	8.434038	−0.996478	0.009939	−0.498239	0.004970	−0.493269	3
Document management system	−51.856029	52.069534	0.052127	8.434038	−0.995900	0.006181	−0.497950	0.003090	−0.494860	6
E-learning	−51.913609	52.069534	0.021427	8.434038	−0.997005	0.002541	−0.498503	0.001270	−0.497232	9
Expertise system	−51.823867	52.069534	0.040927	8.434038	−0.995282	0.004853	−0.497641	0.002426	−0.495215	7
Knowledge maps	−51.907737	52.069534	0.040927	8.434038	−0.996893	0.004853	−0.498446	0.002426	−0.496020	8
Recommender system	−51.836301	52.069534	0.111027	8.434038	−0.995521	0.013164	−0.497760	0.006582	−0.491178	2
Working association	−51.939203	52.069534	0.009427	8.434038	−0.997497	0.001118	−0.498748	0.000559	−0.498190	14