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Knowledge management adoption and assessment for SMEs by a novel MCDM approach

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ABSTRACT

This paper aims to clarify the misunderstanding of high expenditure on knowledge management systems adoption, and provides a novel approach for the most emergent knowledge management components to catch up to the pace of their rivals for the late adopters of knowledge management systems. This paper adopts MCDM (Multiple Criteria Decision Making) approaches to solve this KM adoption problem, and ranks the gaps of the KM aspects in control items to achieve the aspired level of performance. The findings demonstrate that the knowledge management gaps within the service industry are higher than the gaps within the IC (Integrated Circuit) and banking industries. After normalization and computation, the knowledge management gap of the service industry is 0.4399(1), the knowledge management gap of the IC (Integrated Circuit) industry is 0.3651(2), and the knowledge management gap of the banking industry is 0.2820(3). The findings also show that the criteria for weighting in different industry sectors are quite different; and the adoption strategies for different industry sectors should be considered separately according to the SME industry sectors.

1. Introduction

Most SMEs (Small and Medium sized Enterprises) are suffering because of low profits caused by hyper competition and OEM (Original Equipment Manufacturer) dead-end. Moreover, since the middle of 2008, the financial tsunami has caused serious damage to the global economy. Since 80% of the enterprises fall into the category of "Small and Medium Enterprises", they lack the financial and systematic basis to introduce knowledge management practices and make innovations. Several researchers have explored the gaps in the knowledge management activities of enterprises. Their studies reveal that corporate performance is significantly influenced by those gaps. The researchers have stressed the need for further investigation of knowledge management gaps. To this end, we use Grounded Theory to study the gaps in knowledge management activities in enterprises. From our pilot survey, we have discovered that gaps indeed exist between the theory and practice of Knowledge Management; thus, further development and testing of models are necessary.

Our research aims to clarify the misunderstanding of high expenditure on knowledge management systems adoption, and provides a novel approach for the most emergent knowledge management components to catch up with the pace of their rivals for the late adopter of knowledge management systems. We adopt MCDM (Multiple Criteria Decision Making) approach to solve this KM (Knowledge Management) adoption problem (Fig. 1), in which this new method allows the decision maker to understand these gaps of the aspects and rank them to improve those large gaps in control items to achieve the aspired level.

There are certain concepts within the general domain of Knowledge Management that have not been fully explored. We will benefit from a more detailed look at various risks, gaps and strengths [25]. There are five management gaps in the implementation of KM (Knowledge Management) activities and these gaps exist in the links between KM activities and corporate performance. Corporate performance is significantly influenced by these knowledge management gaps. Lin and Tseng [19] explore the gaps of knowledge management activities for the enterprise to build a framework that analyze the corporate knowledge needs, and identify any inhibitors to the success of the implementation activities of the KM system. Their study is based on the literature review, expert interviews and questionnaires.

Recently much research has studied Knowledge Management Maturity Model (KMMM) to examine the knowledge management capability and maturity for organizations recently [7,14–16]. In this paper, we survey the gaps of KMMM (Knowledge Management Maturity Model) achievements, and provide an approach for the ranking of KM aspects by the most-urgent aspects to reach the next capability stage as soon as possible. Group decision-making, the

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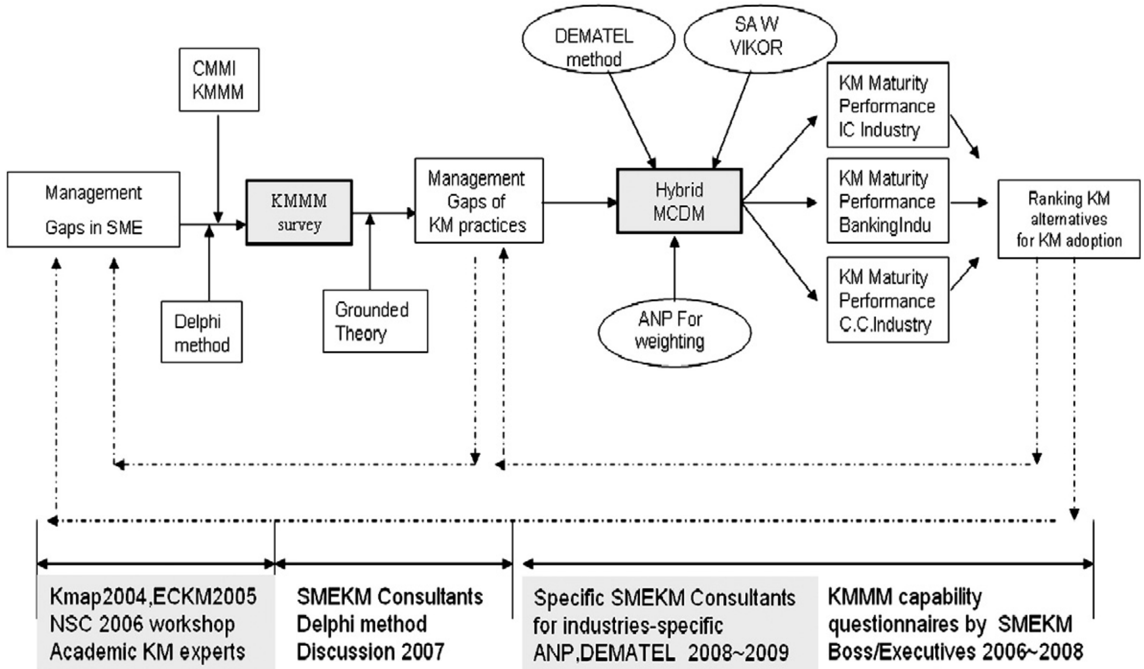


Fig. 1. The hybrid procedures of MCDM (Multiple Criteria Decision Making) for KM adoption [26].

essence of KM, lets us consider multi-dimensional problems for the decision-maker, sets priorities for each decision factor, and assesses rankings for all alternatives.

The remainder of this paper is organized as follows. Section 2 describes the related works to knowledge management capabilities and Knowledge Management Maturity Model. Section 3 describes the Multiple Criteria Decision Making approaches. Section 4 describes the research methods used in this study. Section 5 proposes a novel MCDM approach for SME (Small and Medium sized Enterprises) knowledge management adoption, and Section 6 presents data collected and represented in this study. Finally, in Section 7, we present our conclusions and suggest some directions for future research.

2. Related works

In this knowledge-based economy, knowledge has become an important asset to an organization and, consequently, Knowledge Management has emerged as an issue managers have to deal with. Numerous works on knowledge management capabilities are reported in literature [1,3,8,17,18,33]. In this section, we will discuss the related works in knowledge management capability, Knowledge Management Maturity Model, and knowledge management gaps.

2.1. Knowledge management capability

Knowledge management capability (KMC) is the source for organizations to gain a sustainable competitive advantage. KMC evaluation is a required work with strategic significance [8,18]. Previous KM research has developed integrated management frameworks for building organizational capabilities of Knowledge Management. Based on these frameworks, they propose stage models of organizational knowledge management encompassing the KM process stages [17].

Gold et al. [10] examine the issue of effective Knowledge Management from the perspective of organizational capabilities. They suggest that a knowledge infrastructure consisting of technology, structure, and culture along with knowledge processes architecture of acquisition, conversion, application, and protection is essential for the organizational capabilities of effective Knowledge Management.

2.2. Knowledge Management Maturity Model

Knowledge Management Maturity Modeling (KMMM) has been a major topic of research in recent years [7,14–16]. In practice, a few KMM models [16] have been proposed by consulting firms as well. However, a common KMM model that both academics and practitioners agree on has yet to materialize and moreover, details are often missing from models in practice.

Most KMM models inherit the spirit of the Capability Maturity Model (CMM) [5] of SEI with its five levels of maturity — initial, repeated, defined, managed, and optimizing. Capability, another important attribute of CMM, can be translated into the enabling factors or infrastructure of KM. While most KMM models treat KM as a holistic activity, we view it as a process and divide it into four KM sub-processes, namely knowledge creation, knowledge storage, knowledge sharing, and knowledge application. The added dimension allows us to gain better insight into how KM practices are supported at each maturity level and reflects our emphasis on the need for continuous process improvement.

2.3. Knowledge management gaps

Several researchers have explored the gaps in knowledge management activities of enterprises and identified the links between these activities and corporate performance. Their results reveal that corporate performance is significantly influenced by these management gaps.

Previous research has demonstrated that making a more detailed observation of risks, gaps and strengths is beneficial [25]. According to the findings of Lin and Tseng [19], there are five management gaps in implementation of KM activities and these gaps exist in the links between KM activities and corporate performance [19]. Their study explores the gaps of knowledge management activities for the enterprise to build a framework that analyzes the corporate knowledge needs, and identifies any inhibitors to the success of the implementation activities of the KM system. It shows that corporate performance is significantly influenced by these knowledge management gaps.

3. Some basic concepts for MCDM (Multiple Criteria Decision Making) methods

The decision-making process involves identifying problems, constructing preferences, evaluating alternatives, and determining the best alternative [20,23,24,35,39]. However, when decision-makers evaluate the alternatives with multiple criteria, many problems, such as the weights of the criteria, preference dependence, and conflicts among criteria, seem to complicate the decision-making process and should be resolved by more sophisticated methods.

Decision-making is extremely intuitive when considering single criterion problems, since we only need to choose the alternative with the highest preference rating. However, adopting a knowledge management system is not just a single criterion problem. Decision-makers need to evaluate the alternatives based on multiple criteria. Many problems, such as the weights of criteria, preference dependence, and conflicts among criteria, seem to complicate the decision-making process and should be resolved by more sophisticated methods.

3.1. The MCDM (Multiple Criteria Decision Making) methodology processes

Dealing with Multiple Criteria Decision Making (MCDM) problems involves 5 key steps.

(1) Identification of the problem/issue: decision-makers need to identify the nature of the research problem. They must determine specifically which criteria should be considered, and which decision-making strategies should be adopted.
(2) Problem structuring: practitioners/decision-makers need to identify the goals, values, constraints, external environment, key issues, uncertainties, and stakeholders of this enterprise. In this step, we need to collect the appropriate data or information so that the preferences of decision-makers can be correctly identified and considered.
(3) Model building: decision-makers then specify the alternatives, define all criteria, and elicit values for model building. This process allows them to compile a set of possible alternatives or strategies in order to guarantee that the goal will be achieved.
(4) Using the model to inform and challenge established thinking: especially decision-makers collect and synthesize information, challenge people's intuition, suggest other new alternatives, and analyze the robustness and sensitivity of the model.
(5) Developing an action plan: in the final step, an action plan is constructed as a solution. In other words, we can select the appropriate method to help us to evaluate and rank the possible alternatives or strategies (i.e., determine the best alternative).

3.2. Analytic Network Process (ANP)

The Analytic Network Process (ANP) is an extension of Analytic Hierarchy Process (AHP) by Saaty [30] to overcome the problem of interdependence and feedback among criteria or alternatives [30–32]. Although the AHP and the ANP derive ratio scale priorities by making pair-wise comparisons of elements (such as dimensions or criteria), there are differences between them. The first is that the AHP is a special version of the ANP; the ANP handles dependence within a cluster (inner dependence) and among different clusters (outer dependence). Secondly, the ANP is a nonlinear structure, while the AHP is hierarchical and linear, with the goal at the top and the alternatives in the lower levels [31] based on the dynamic concept of the Markov chain [32].

The initial step of the ANP is to compare the criteria in the entire system to form a super-matrix through pair-wise comparisons by asking "How much importance does one criterion have compared to another criterion, with respect to our interests or preferences?" The relative importance is determined using a scale of 1–9 representing equal importance to extreme importance [11].

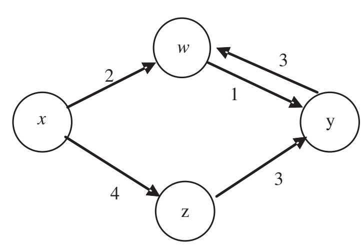
3.3. The DEMATEL (Decision MAking Trial and Evaluation Laboratory) technique

The DEMATEL (Decision MAking Trial and Evaluation Laboratory) method gathers collective knowledge to capture the causal relationships between strategic criteria. This paper applies the DEMATEL technique in the strategic planning of Knowledge Management to help managers address the above situations and related questions.

Because evaluation of knowledge management capabilities cannot accurately estimate each considered criterion in terms of numerical values for the alternatives, fuzziness is an appropriate approach. The DEMATEL technique is an emerging method that gathers group knowledge to capture the causal relationships between criteria. It is especially practical and useful for visualizing the structure of complicated causal relationships with matrices or digraphs, which portray the contextual relations between the elements of a system, where a numeral represents the strength of influence [34]. Therefore, the DEMATEL technique can convert the relationship between the causes and effects of criteria into an intelligible structural model of the system.

The DEMATEL technique is utilized to investigate the interrelations among criteria to build a Network Relationship Map (NRM). This technique has been successfully applied in many situations, such as the development of strategies, management systems, e-learning evaluations, and Knowledge Management [20,34,37]. The method can be arranged as follows:

Step 1: Obtain the direct-influence matrix by scores. Respondents are required to point out the degree of direct influence among each criterion. We suppose that the comparison scales, 0, 1, 2, 3 and 4, stand for the levels from "no influence" to "very high influence". Then, the graph which can describe the interrelationships between the criteria of the system is shown in the figure below. For instance, an arrow from w to y symbolizes that w impacts on y, and the score of influence is 1. The direct-influence matrix, $\boldsymbol{A}$, can be derived by indicated one criterion i impact on another criterion j as a_{ij}.



$$\boldsymbol{A} = \begin{bmatrix} a_{11} & \cdots & a_{1j} & \cdots & a_{1n} \\ \vdots & & \vdots & & \vdots \\ a_{i1} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & & \vdots & & \vdots \\ a_{n1} & \cdots & a_{nj} & \cdots & a_{nn} \end{bmatrix}$$

Step 2: Calculate the normalized direct-influence matrix $\boldsymbol{X}$. $\boldsymbol{X}$ can be calculated by normalizing $\boldsymbol{A}$ through Eqs. (1) and (2).

$$\mathbf{X} = m \cdot \mathbf{A} \tag{1}$$

$$m = \min\left[\frac{1}{\max_i \sum_{j=1}^{n} |a_{ij}|}, \frac{1}{\max_j \sum_{i=1}^{n} |a_{ij}|}\right] \tag{2}$$

Step 3: Derive the total direct-influence matrix $\boldsymbol{T}$. $\boldsymbol{T}$ of NRM (Network Relationship Map) can be derived by using a formula (3), where $\boldsymbol{I}$ denotes the identity matrix; i.e., a continuous decrease of the indirect effects of problems along the powers of $\boldsymbol{X}$, e.g., $\boldsymbol{X}^2, \boldsymbol{X}^3, \ldots, \boldsymbol{X}^q$ and $\lim_{q\to\infty} X^q = [0]_{n\times n}$, where $X = [x_{ij}]_{n\times n}$,

$0 \le x_{ij} \le 1$, $0 < \sum_{j=1}^{n} x_{ij} \le 1$ and $0 < \sum_{i=1}^{n} x_{ij} \le 1$. If at least one row or column of summation is equal to 1, but not all, then $\lim_{q\to\infty} X^q = [0]_{n\times n}$. The total-influence matrix is listed as follows.

$$\begin{aligned} \boldsymbol{T} &= \boldsymbol{X} + \boldsymbol{X}^2 + \cdots + \boldsymbol{X}^q \\ &= \boldsymbol{X}\left(\boldsymbol{I} + \boldsymbol{X} + \boldsymbol{X}^2 + \cdots + \boldsymbol{X}^{q-1}\right)(\boldsymbol{I}-\boldsymbol{X})(\boldsymbol{I}-\boldsymbol{X})^{-1} \\ &= \boldsymbol{X}(\boldsymbol{I}-\boldsymbol{X}^q)(\boldsymbol{I}-\boldsymbol{X})^{-1} \end{aligned}$$

when q→∞, $\boldsymbol{X}^q = [0]_{n\times n}$, then

$$\boldsymbol{T} = \boldsymbol{X}(\boldsymbol{I}-\boldsymbol{X})^{-1} \tag{3}$$

where $T = [t_{ij}]_{n\times n}$, $i,j = 1,2,\ldots,n$.

Step 4: Construct the NRM based on the vectors r and s. The vectors $\boldsymbol{r}$ and $\boldsymbol{s}$ of matrix $\boldsymbol{T}$ represent the sums of rows and columns respectively, which are shown as Eqs. (4) and (5).

$$\boldsymbol{r} = [r_i]_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} \tag{4}$$

$$s = \left[\boldsymbol{s}_j\right]_{n\times 1} = \left[\sum_{i=1}^{n} t_{ij}\right]'_{1\times n} \tag{5}$$

where $\boldsymbol{r}_i$ denotes the sum of the i-th row of matrix $\boldsymbol{T}$ and displays the sum of direct and indirect effects of criterion i on another criteria. Also, $\boldsymbol{s}_j$ denotes the sum of the j-th column of matrix $\boldsymbol{T}$ and represents the sum of direct and indirect effects that criterion j has received from another criteria. Moreover, when $i = j$ ($\boldsymbol{r}_i + \boldsymbol{s}_i$), it presents the index of the degree of influences given and received; i.e., ($\boldsymbol{r}_i + \boldsymbol{s}_i$) reveals the strength of the central role that factor i plays in the problem. If ($\boldsymbol{r}_i - \boldsymbol{s}_i$) is positive representing that other factors are impacted by factor i. On the contrary, if ($\boldsymbol{r}_i - \boldsymbol{s}_i$) is negative, other factors have influences on factor i and thus the NRM can be constructed [22,34]. Therefore, a causal graph can be achieved by mapping the dataset of ($\boldsymbol{r}_i + \boldsymbol{s}_i$, $\boldsymbol{r}_i - \boldsymbol{s}_i$), providing a valuable approach for decision-making. The vector $\boldsymbol{r}$ and vector $\boldsymbol{s}$ express the sum of the rows and the sum of the columns from the total-influence matrix $T = [t_{ij}]_{n\times n}$, respectively, and the superscript denotes the transpose [2]. Now we call the total-influence matrix $T_C = [t_{ij}]_{n\times n}$ obtained by criteria and $T_D = [t_{ij}^D]_{m\times m}$ obtained by dimensions (clusters) from experts' opinions. Then we normalize the ANP weights of dimensions (clusters) by using influence matrix $\boldsymbol{T}_D$.

3.4. VIKOR (the Serbian name, VlseKriterijumska Optimizacija I Kompromisno Resenje)

Opricovic [28] and Opricovic and Tzeng (2002) developed VIKOR (the Serbian name, VlseKriterijumska Optimizacija I Kompromisno Resenje, means Multi-criteria Optimization and Compromise Solution) [27–29]. The basic concept of VIKOR lies in defining the positive and negative ideal solutions first. The positive ideal solution indicates the alternative with the highest value (score of 100), while the negative ideal solution indicates the alternative with the lowest value (score of 0). In our study, the highest performance value of SMEs (Small and Medium sized Enterprises) is 5, and the lowest performance value is 0. They are used to help DMs (Decision Makers) by representing the present status of KM components for KM assessment and adoption.

The VIKOR method is developed as a multi-criteria decision-making method to solve a discrete decision problem with non-commensurable and conflicting criteria [27,29]. The method ranks a set of alternatives, and selects the alternative with the highest score. It then suggests compromise solutions to a problem with conflicting criteria in order to help practitioners reach a final decision. Here, the compromise solution is the feasible solution that is the closest to the ideal, and a compromise means an agreement reached on the basis of mutual concessions. The TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method, which is also a distance-based approach, derives a solution with the shortest distance from the positive ideal solution and the farthest distance from the negative-ideal solution, but it does not consider the relative importance of the distances. A detailed comparison of TOPSIS and VIKOR is presented in Opricovic and Tzeng [29].

Multi-criteria ranking and compromise solutions

Criteria	Weights	Alternatives					$\max_k$ (or aspired value)	$\min_k$ (or the worst value)
		a_1	…	a_k	…	a_m		
c_1	w_1	x_{11}	…	x_{k1}	…	x_{m1}	x_1^*	x_1^-
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
c_i	w_i	x_{i1}	…	x_{ik}	…	x_{im}	x_i^*	x_1^-
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
c_n	w_n	x_{n1}	…	x_{nk}	…	x_{nm}	x_n^*	x_n^-

(Data matrix: larger is better)

$$d_k^p = \left\{\sum_{i=1}^{n}\left[w_i\left(\frac{x_i^* - x_{ik}}{x_i^* - x_i^-}\right)\right]^p\right\}^{1/p}$$

when $d_k^{p=1} = S_k = \sum_{i=1}^{n} w_i\left(\frac{x_i^* - x_{ik}}{x_i^* - x_i^-}\right)$ for average degree of regret (average gap) $d_k^{p=\infty} = Q_k = \max_i\left\{\left(\frac{x_i^* - x_{ik}}{x_i^* - x_i^-}\right) | i = 1, 2, \ldots, n\right\}$ for maximal degree of regret (priority improvement).

Ranking (small is better for distance S_k and Q_k)

$$R_k = v\left[(S_k - S^*)/(S^- - S^*)\right] + (1-v)[(Q_k - Q^*)/(Q^- - Q^*)],$$

Let $v = 0.5$ be the majority criteria, where, $S = \min_k S_k$ (or $S^* = 0$, i.e., achieving aspired level, gap equals zero), $S^- = \max_k S_k$ (or $S^- = 1$ denotes that the index is the worst value) and $Q = \min_k Q_k$ ($Q^* = 0$), $Q^- = \max_k Q_k$ (or $Q^- = 1$).

3.5. Simple Additive Weighting method (SAW)

Churchman and Ackoff [4] firstly utilized the SAW method to cope with portfolio selection problem [4]. SAW method is probably the best-known and widely used method for MCDM (Multiple Criteria Decision Making). Because of the simplicity, the SAW is the most popular method in the MCDM (Multiple Criteria Decision Making) problems and the best alternative can be derived by the following equation:

$$A^* = \left\{u_k(x) | \max_k u_k(x)\right\} \tag{6}$$

and

$$u_k(x) = \sum_{i=1}^{n} w_i r_{ik}(x) \tag{7}$$

where $u_k(x)$ denotes the utility of the k-th alternative, w_i denotes the weights of the i-th criterion, and $\boldsymbol{r}_{ik}(x)$ is the normalized preferred ratings of the k-th alternative with respect to the i-th criterion. In addition, the normalized preferred ratings ($\boldsymbol{r}_{ik}(x)$) of the i-th alternative with respect to the j-th criterion can be defined by:

For benefit criteria, $r_{ik}(x) = \frac{x_{ik}}{x_i^*}$, where $x_i^* = \max_k x_{ik}$, and it is clear $0 \le \boldsymbol{r}_{ik}(x) \le 1$; for cost criteria, $r_{ik}(x) = \frac{1/x_{ik}}{1/x_i^*} = \frac{\min_k x_{ik}}{x_{ik}}$; or setting aspired level (the best value) as x_i^* and the worst value as x_i^-, then $r_{ik} = \frac{x_{ik} - x_i^-}{x_i^* - x_i^-}$.

where x_{ik} is the normalized preferred ratings of the k-th alternative with respect to the i-th criterion.

4. The research architectures and methods for Knowledge Management

Knowledge management adoption is also an MCDM (Multiple Criteria Decision Making) problem. The first step involves identifying how many attributes or criteria are involved in the adoption of a knowledge management system. Next, the appropriate data or information must be collected so that the preferences of different stakeholders can be correctly identified and considered (i.e., constructing the preferences). Our goal is to establish objective and measurable patterns to define the anticipated achievements of Knowledge Management by conducting group-decision analysis. Group decision-making as previously mentioned, the essence of KM, allows decision-makers to consider multi-dimensional problems, sets priorities for each decision factor, and assesses the rankings of all alternatives.

The procedures of MCDM (Multiple Criteria Decision Making) for KM adoption in this study:

1. More than sixty KM experts were invited and academic focus groups were constructed in KMAP2004 (International Conference of Knowledge Management in Asia Pacific), ECKM2005 (European Conference of Knowledge Management 2005), workshop of NSC2006 (National Science Council in Taiwan) to address the research issues of knowledge management gaps between practical activities and theoretical findings of enterprises to identify the links between these activities and corporate performance.
2. In 2007, we joined Knowledge Management Project of Small and Medium sized Enterprises (SMEKM) of the Taiwan Ministry of Economic Affairs. The Delphi method was used to clarify the guidelines and bottlenecks of Small and Medium sized Enterprises. More than forty five KM domain experts/consultants were involved in this KMMM (Knowledge Management Maturity Model) surveys. After the SMEKM forum and pilot survey, we discovered that a gap indeed existed between the theory and practice of Knowledge Management; thus, Grounded Theory was used for further development and testing of our model to investigate the unknown reasons behind the SMEKM report.
3. Between the years of 2008 and 2009, we clarified the KM gaps which existed in KM practices of SMEs and proposed a hybrid MCDM (Multiple Criteria Decision Making) approach combining DEMATEL, SAW, VIKOR and ANP for weighting to rank the gaps that had not been reduced or improved (the unimproved gaps) for the alternatives/projects or aspects of a project to get the most benefit and reach the aspired KMMM (Knowledge Management Maturity Model) level.
4. From the years of 2006 to 2009, we collected empirical data by using the KMMM (Knowledge Management Maturity Model) capability questionnaires to investigate KM maturity performance from CEOs (Chief Executive Officers)/practitioners of three different industries, namely the Integrated Circuits industry, banking industry, and services industry. Performance values of KM aspects of SMEs were multiplied with the weighting values used to rank the KM gaps and KM alternatives for knowledge management adoption.

4.1. Grounded Theory

From our pilot survey, we discovered that a gap indeed exists between the theory and practice of Knowledge Management; thus, further development and testing of models is necessary.

After we studied the results of interviews with senior managers from Taiwanese banking organizations, we discovered something interesting needed to be discussed. Then we adopt Grounded Theory (GT), which has become popular for conducting management research because it can be used to identify emerging issues from interviews. This forms the first phase of this doctoral study. Our goal is to develop a knowledge management model for these organizations.

Grounded Theory (GT), which is most often associated with the social sciences, such as psychology, was developed by the sociologists Barney Glaser (1930–Present) and Anselm Strauss (1916–1996). Their collaborative research on terminally ill hospital patients led them to write the book Awareness of Dying. As a result of their research, they developed the constant comparative method, subsequently known as Grounded Theory [9], which was developed as a systematic methodology [9]. Its name underscores the generation of theories from data. By following the principles of Grounded Theory, researchers can formulate a theory, either substantive (setting specific goals) or formal, about the phenomena they are studying and evaluating, e.g., gaps in Knowledge Management.

4.2. Delphi method

The Delphi method originated in a series of studies conducted by the RAND Corporation in the 1950s [13]. The objective was to develop a technique to obtain the most reliable consensus from a group of experts [6]. While researchers have developed variations of the method since its introduction, Linstone and Turoff [21] captured its common characteristics in the following description: Delphi may be characterized as a method for structuring a group communication process; so the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem [21]. To accomplish this 'structured communication,' certain aspects should be provided: some feedback of individual contributions of information and knowledge; some assessment of the group judgment or viewpoint; some opportunity for individuals to revise their views; and some degree of anonymity for individual responses [21].

The Delphi technique enables a large group of experts to be surveyed cheaply, usually by mail using a self-administered questionnaire (although computer communications also have been used), with few geographical limitations on the sample. Specific situations have included a round in which the participants meet to discuss the process and resolve any uncertainties or ambiguities in the wording of the questionnaire [13].

5. Building a novel MCDM (Multiple Criteria Decision Making) model with ANP, DEMATEL, and VIKOR for SMEKM adoption

Because practitioners often manage several KM alternatives with conflicting, and wonder what are the differences of KM practices with other competitors? What is the next step? How can we assess and measure the practiced activities of knowledge management process? These questions should be answered. We wish to consider several noncommensurable criteria to reduce the gaps to achieve the aspired KMMM (Knowledge Management Maturity Model) stage by ranking the gaps that have not been reduced or improved (the unimproved gaps) for the alternatives/projects or aspects of a project to get the most benefit and reach the aspired KMMM (Knowledge Management Maturity Model) level.

As any criterion may impact each other, this study used the DEMATEL (Decision MAking Trial and Evaluation Laboratory) technique to acquire the structure of the MCDM (Multiple Criteria Decision Making) problems. The weights of each criterion from the structure are obtained by utilizing the ANP (Analytic Network Process). The VIKOR technique will be leveraged for calculating compromise ranking and gaps of the alternatives. In short, the framework of evaluation contains three main phases: (1) constructing the Network Relationship Map (NRM) among criteria by the DEMATEL technique, (2) calculating the weights of each criterion by the ANP based on the NRM, and (3) ranking or improving the priorities of alternatives of portfolios through the VIKOR.

5.1. The ANP (Analytic Network Process) for calculating weights of criteria based on the NRM

The AHP (Analytic Hierarchy Process) supposes independence among criteria, which is not reasonable in the real world. Saaty [30] thus extended AHP to ANP (Analytic Network Process) to resolve problems with dependence or feedback between criteria, which primarily divides problems into numerous different clusters and every cluster includes multiple criteria [30–32]. Moreover, there is outer dependence among clusters and inner dependence within the criteria of clusters. In addition, we figured the relative weights of criteria of respective matrices by pair-wise comparison and modifying the weights as eigenvectors. Then we integrated multiple matrices into a super matrix, because the capacity to examine the inner and outer dependence of clusters is the largest benefit of a super matrix as in Eq. (8).

There are three steps for the decision process of ANP. First, the decision problem and the structure of problem were built to offer an evident depiction of the problem and separate it into a relation network structure. Second, not only is the pair-wise comparison matrix established, but also eigenvalue and eigenvector were figured.

$$\boldsymbol{W} = \begin{array}{c} \\ \\ C_1 \begin{array}{c} e_{11} \\ e_{12} \\ \vdots \\ e_{1n_1} \end{array} \\ C_2 \begin{array}{c} e_{21} \\ e_{22} \\ \vdots \\ e_{2n_2} \end{array} \\ \vdots \\ C_n \begin{array}{c} e_{n1} \\ e_{n2} \\ \vdots \\ e_{nn_n} \end{array} \end{array} \begin{array}{c} \begin{array}{ccccc} C_1 & & C_2 & \cdots & C_n \\ e_{11}e_{12}\cdots e_{1n_1} & & e_{21}e_{22}\cdots e_{2n_2} & \cdots & e_{n1}e_{n2}\cdots e_{nn_n} \end{array} \\ \begin{bmatrix} \boldsymbol{W}_{11} & \cdots & \boldsymbol{W}_{12} & \cdots & \boldsymbol{W}_{1n} \\ \boldsymbol{W}_{21} & \cdots & \boldsymbol{W}_{22} & \cdots & \boldsymbol{W}_{2n} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{W}_{n1} & \cdots & \boldsymbol{W}_{n2} & \cdots & \boldsymbol{W}_{nn} \end{bmatrix} \end{array} \tag{8}$$

Pair-wise comparison is composed of clusters and criteria. Furthermore, the pair-wise comparison of clusters was separated into comparison of criteria within and between clusters. We utilize ratio scale (1–9) to determine the level of importance of the comparison. In addition, the data deriving from the survey of ANP were combined and transferred into pair-wise comparison matrix by geometric average. After building the matrix, we received the eigenvector $\boldsymbol{W}_{ii}$ through an equation: $\boldsymbol{Aw} = \lambda_{\max}\boldsymbol{w}$, where $\boldsymbol{A}$ is pair-wise comparison matrix, $\boldsymbol{w} = (w_1,\ldots,w_i,\ldots,w_n)'$ is the eigenvector, w_i is the eigenvalue, then

$$\lambda_{\max} = \frac{1}{n}\sum_{i=1}^{n} \frac{(\boldsymbol{Aw})_i}{\boldsymbol{w}_i} \tag{9}$$

where $(\boldsymbol{Aw})_i = \sum_{j=1}^{n} a_{ij}w_j$ and n equals the number of comparative criteria. Third, the super-matrix, tagged $\boldsymbol{W}$ was formed. It was constructed by the dependence table obtained from the interrelations among criteria, and the eigenvectors received from the pair-wise comparison matrix served as the weights of it. No inner dependence among criteria or clusters was shown by a blank or zero. By Wu and Lee [38], the usage of power matrix by $\boldsymbol{W}^h$ (multiplication) and $\lim_{h\to\infty}\boldsymbol{W}^h$ is a fixed convergence value; therefore, we can acquire weights in every criterion [38].

5.2. The revised VIKOR for ranking and improving the alternatives

Opricovic [28] proposed the compromise ranking method (VIKOR) as one applicable technique to implement within MCDM (Multiple Criteria Decision Making) [28,29]. Suppose the feasible alternatives are represented by $A_1, A_2,\ldots, A_k,\ldots, A_m$. The performance score of alternative A_k and the j-th criterion is denoted by f_{ik}; w_i is the weight (relative importance) of the i-th criterion, where $i = 1, 2,\ldots, n$, and n is the number of criteria. Development of the VIKOR method began with the following form of L_p-*metric*:

$$L_k^p = \left\{\sum_{i=1}^{n}\left[w_i(|f_i^* - f_{ik}|)/(|f_i^* - f_{ik}^-|)\right]^p\right\}^{1/p}, \tag{10}$$

where $1 \le p \le \infty$; alternative $k = 1,2,\ldots,m$; weight w_i is derived from the ANP. To formulate the ranking and gap measure $L_k^{p=1}$ (as S_k) and $L_k^{p=\infty}$ (as Q_k) are used by VIKOR [28,29,34–37].

$$S_k = L_k^{p=1} = \sum_{j=1}^{n}\left[w_i(|f_i^* - f_{ik}|)/(|f_i^* - f_i^-|)\right] \tag{11}$$

$$Q_k = L_k^{p=\infty} = \max_i\{(|f_i^* - f_{ik}|)/(|f_i^* - f_i^-|) \mid i = 1, 2, \cdots, n\}. \tag{12}$$

The compromise solution $\min_k L_k^p$ shows the synthesized gap to be the minimum and will be selected for its value to be the closest to the aspired level. Besides, the group utility is emphasized 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 in each dimension/criterion. Consequently, $\min_k S_k$ stresses the maximum group utility; however, $\min_k Q_k$ accents on the selecting the minimum from the maximum individual regrets/gaps. The compromise ranking algorithm VIKOR has four steps according to the above-mentioned ideas.

Step 1: Obtain an aspired or tolerable level. We calculate the best f_i^* values (aspired level) and the worst f_i^- values (tolerable level) of all criterion functions, $i = 1,2,\ldots,n$. Suppose the i-th function denotes benefits: $f_i^* = \max_k f_{ik}$ (or setting the aspired level as f_i^*) and $f_i^- = \min_k f_{ik}$ (or setting the worst value as f_i^-) or these values can be set by decision makers, i.e., f_j^* = aspired level and f_j^- = the worst value. Further, an original rating matrix can be converted into a normalized weight-rating matrix by using the equation:

$$r_{ik} = (|f_i^* - f_{ik}|)/(|f_i^* - f_i^-|). \tag{13}$$

Step 2: Calculate mean of group utility and maximal regret. The values can be computed respectively by $S_k = \sum_{i=1}^{n} w_i r_{ik}$ (the synthesized (average) gap for all criteria) and $\mathbf{Q}_k = \max_i\{r_{ik} \mid i = 1,2,\ldots,n\}$ (the maximal gap for prior improvement).

Step 3: Calculate the index value. The value can be counted by

$$R_k = v(S_k - S^*)/(S^- - S^*) + (1 - v)(Q_k - Q^*)/(Q^- - Q^*), \tag{14}$$

where $k = 1,2,\ldots,m$.
$S^* = \min_i S_i$ or setting $S^* = 0$ and $S^- = \max_i S_i$ or setting $S^- = 1$; $Q^* = \min_i Q_i$ or setting $Q^* = 0$ and $Q^- = \max_i Q_i$ or setting $Q^- = 1$; and v is presented as the weight of the strategy of the maximum group utility.

Step 4: Rank or improve the alternatives for a compromise solution. Order them decreasingly by the value of S_k, Q_k and R_k. Propose as a compromise solution the alternative $(A^{(1)})$ which is arranged by the measure $\min\{R_k \mid k = 1,2,\ldots,m\}$ when the two conditions are satisfied:

C1. Acceptable advantage: $R(A^{(2)}) - R(A^{(1)}) \ge 1/(m-1)$, where $A^{(2)}$ is the second position in the alternatives ranked by R.

C2. Acceptable stability in decision making: Alternative $A^{(1)}$ must also be the best ranked by S_k or/and Q_k. When one of the conditions is not satisfied, a set of compromise

Table 1
The initial influence matrix ***A*** for criteria (banking industry).

Criteria	KCT	KCS	KCC	KSHT	KSHS	KSHC	KST	KSS	KSC	KAT	KAS	KAC
Knowledge Creation Technology (KCT)	0	0.076923	0.038462	0.076923	0.076923	0.038462	0.076923	0.076923	0.038462	0.076923	0.076923	0.038462
Knowledge Creation Structure (KCS)	0.115385	0	0.115385	0.038462	0.115385	0	0.038462	0.076923	0.038462	0.038462	0.076923	0.038462
Knowledge Creation Culture (KCC)	0.076923	0.115385	0	0	0	0.115385	0	0	0.115385	0	0	0.115385
Knowledge SHaring Technology (KSHT)	0.115385	0.038462	0.038462	0	0.076923	0.115385	0.076923	0.038462	0.038462	0.076923	0.076923	0.038462
Knowledge SHaring Structure (KSHS)	0.115385	0.115385	0.076923	0.115385	0	0.115385	0.115385	0.076923	0.115385	0.038462	0.076923	0.038462
Knowledge SHaring Culture (KSHC)	0	0.038462	0.076923	0.115385	0.038462	0	0.038462	0.076923	0.076923	0.038462	0.038462	0.076923
Knowledge STorage Technology (KST)	0.076923	0.038462	0.038462	0.115385	0.038462	0.038462	0	0.076923	0.076923	0.038462	0.038462	0
Knowledge STorage Structure (KSS)	0	0.076923	0	0	0.076923	0.038462	0.076923	0	0.115385	0.038462	0.076923	0.038462
Knowledge STorage Culture (KSC)	0	0.038462	0.076923	0.076923	0.076923	0.115385	0.076923	0.076923	0	0.038462	0.038462	0.038462
Knowledge Application Technology (KAT)	0.076923	0	0	0.076923	0.038462	0.038462	0.076923	0.038462	0.038462	0	0.076923	0.076923
Knowledge Application Structure (KAS)	0	0.076923	0.076923	0	0.076923	0.038462	0	0.076923	0	0.076923	0	0.076923
Knowledge Application Culture (KAC)	0.038462	0.076923	0.076923	0	0.038462	0.076923	0	0.038462	0.076923	0.076923	0.115385	0

solutions is selected. The compromise solutions are composed of: (1) Alternatives $A^{(1)}$ and $A^{(2)}$ if only condition C2 is not satisfied or (2) Alternatives $A^{(1)}$, $A^{(2)}$,…,$A^{(M)}$ if condition C1 is not satisfied. $A^{(M)}$ is calculated by the relation $R(A^{(M)})-R(A^{(1)})<1/(m-1)$ for maximum M (the positions of these alternatives are close).

The compromise-ranking method (VIKOR) is applied to determine the compromise solution and the solution is adoptable for decision-makers in that it offers a maximum group utility of the majority (shown by min S), and a maximal regret of minimum individuals of the opponent (shown by min Q). This model utilizes the DEMATEL and ANP processes to get the weights of criteria with dependence and feedback and employs the VIKOR method to acquire the compromise solution.

5.3. Assessing the KM maturity of the IC (Integrated Circuit) design, banking, and services industries

In this section, we present an empirical study for applying the proposed model to assess the knowledge management gaps in the industries mentioned above. First, we use the same weighted preferences for knowledge management components to assess the three industries, and then compile a profile of the knowledge management gaps and the best adoption strategies for the industries. Second, based on the weighted preferences of knowledge management components provided by different domain experts, we discuss the results of using those preferences to assess the three industries and determine the best KM adoption strategy for each one.

The knowledge management gaps between the theoretical knowledge management practices and practical knowledge management activities of enterprises have significantly influenced corporate performance. Therefore, proper measurement and decision-making processes are critical for knowledge management adoption and success. In the context of strategic goals and transformation, using different KM alternatives will influence resource allocation and overall achievement of success. Group decision-making is a process where experts make decisions and consolidate an optimal strategy.

6. Data collection and representation

6.1. Constructing the NRM by DEMATEL

To analyze the interrelationships between the twelve determinants summarized through literatures, the DEMATEL method introduced in Section 3.3 will be utilized in the decision problem structure.

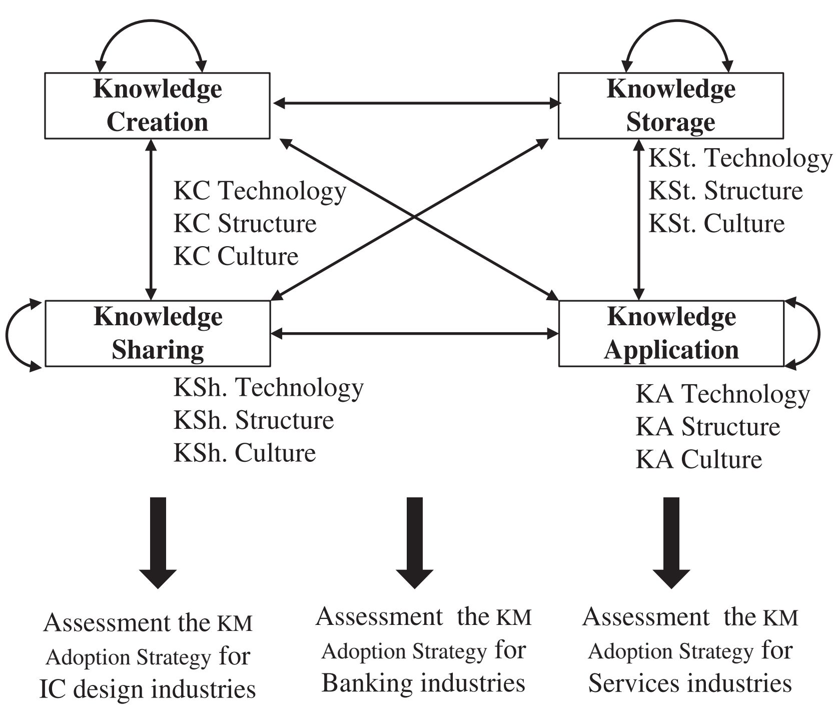


Fig. 2. The KM adoption strategy for three different industries.

First, the direct influence matrix $\boldsymbol{A}$ for criteria was presented (see Table 1). Then, the normalized direct-influence matrix $\boldsymbol{S}$ for criteria can be calculated by Eq. (1). Third, the total direct influence matrix $\boldsymbol{T}$ for criteria/dimensions was derived based on Eq. (3). Finally, the NRM (Network Relationship Map) was constructed by the $\boldsymbol{r}$ and $\boldsymbol{s}$ (Eqs. (4) and (5)) in the total direct influence matrix $\boldsymbol{T}$ as shown in Fig. 2.

6.2. Calculating weights of each criterion by ANP

Many experts were recruited including SME (Small and Medium sized Enterprises) consultants, knowledge management domain scholars, and executive managers of SMEs in several stages. There are twenty-five SME consultants recruited from SMEKM (Knowledge Management Plan for Small and Medium Enterprises) project of the Small and Medium Enterprise Administration, Ministry of Economic Affairs, Taiwan. Fifteen knowledge management domain scholars in ECKM2005 (6th European Conference on Knowledge Management), seven knowledge management domain scholars in Kmap2004 (International Conference on Knowledge Management in Asia Pacific), and nine knowledge management domain scholars in Taiwan NSC (National Science Council) doctoral students research workshop in 2007 were also invited. Finally, KM performance questionnaire data from SME executive managers in SMEKM project, EMBA (Executive Master of Business Administration) program students of NTU (National Taiwan University, Taiwan), NCCU (National Chengchi University, Taiwan), NTPU (National Taipei University, Taiwan), and NCTU (National Chiao Tung University, Taiwan) was collected. According to their expertise of industry sectors, industry-specific SME consultants and knowledge management domain scholars were invited to complete the ANP and DEMATEL questionnaires from different industry perspectives. The executive managers of SMEs were invited to complete the matrix questionnaire for the performance value of their organizational knowledge management capability.

The level of importance (global weights) of 12 criteria can be calculated by ANP shown as Tables 1–4. Results showed that experts were most concerned with Knowledge STorage Culture (rank 1) and Knowledge SHaring Culture (rank 2), and least concerned with Knowledge Application Technology (rank 12) and Knowledge STorage Technology (rank 11).

6.3. Compromise ranking by VIKOR

The VIKOR technique was applied for compromise ranking after the weights of determinants were calculated by ANP in Table 4. Calculation results (Table 5) demonstrated that the total gaps were highest in the services industry, followed by the IC (Integrated Circuit) industry and the banking industry. Therefore, both VIKOR and ANP came to the same conclusions that the KM adoption strategies provided by this study indicated that services industry practitioners are suggested to focus their investment in KM gaps.

When considering the KMCs (knowledge management components), it seems to a serious mistake to apply the same weighting preferences across industries (Table 6). The KMC weighting preference of the banking industry is quite different from both the KMC weighting preferences of the IC (Integrated Circuit) industry and the service industry. Therefore, we should assess the KMC capability of

Table 2
The sum of influences given and received on dimensions (banking industry).

	Dimension	$\boldsymbol{r}_i$	$\boldsymbol{s}_i$	$\boldsymbol{r}_i+\boldsymbol{s}_i$	$\boldsymbol{r}_i-\boldsymbol{s}_i$
Knowledge Creation	D_1	5.4276	5.3865	10.8141	0.0411
Knowledge SHaring	D_2	6.5061	5.6084	12.1144	0.8977
Knowledge STorage	D_3	5.0086	5.4958	10.5044	-0.4872
Knowledge Application	D_4	4.5928	5.0444	9.6371	-0.4516

Table 3
Weighting the unweighted super-matrix based on total influence normalized matrix (banking industry).

	Knowledge Creation Technology	Knowledge Creation Structure	Knowledge Creation Culture	Knowledge SHaring Technology	Knowledge SHaring Structure.	Knowledge SHaring Culture.	Knowledge STorage Technology	Knowledge STorage Structure	Knowledge STorage Culture	Knowledge Application Technology.	Knowledge Application Structure	Knowledge Application Culture
Knowledge Creation Technology	0.06345620	0.10077795	0.08692885	0.10414359	0.08544691	0.05830946	0.08869009	0.05485304	0.05392349	0.11776410	0.05015476	0.06492572
Knowledge Creation Structure	0.11304172	0.05999107	0.11845530	0.07725408	0.09169038	0.08925526	0.07412048	0.11325413	0.08153067	0.07131082	0.10497532	0.09571033
Knowledge Creation Culture	0.08495168	0.10068059	0.05606545	0.07187047	0.07613085	0.10570342	0.06815391	0.06285731	0.09551033	0.06411628	0.09806112	0.09255514
Knowledge SHaring Technology	0.08614570	0.07201157	0.05525401	0.05581322	0.09512415	0.11250879	0.11855249	0.06513007	0.08630336	0.09542590	0.05901901	0.05801885
Knowledge SHaring Structure	0.09041978	0.11410316	0.06096366	0.08968982	0.05894947	0.07757949	0.08054046	0.12116961	0.08601445	0.07974976	0.12185552	0.08772273
Knowledge SHaring Culture	0.07623523	0.06668598	0.13658304	0.11099749	0.10242691	0.06641225	0.08564541	0.09843867	0.11242055	0.07333005	0.06763118	0.10276412
Knowledge STorage Technology	0.08382554	0.07078848	0.04900293	0.09384944	0.08595311	0.06811593	0.05489448	0.08991790	0.09475343	0.08840888	0.05237778	0.04906488
Knowledge STorage Structure	0.08950142	0.09446741	0.06192273	0.08315777	0.08087607	0.09313759	0.10330958	0.05516700	0.10133690	0.07433969	0.11369118	0.08186347
Knowledge STorage Culture	0.07648150	0.08455257	0.13888280	0.08636249	0.09654052	0.10211617	0.10752563	0.12064480	0.06963936	0.07578261	0.07246222	0.10760283
Knowledge Application Technology	0.07975629	0.06653576	0.04840045	0.07667973	0.06596026	0.06382855	0.07621670	0.06175417	0.06664314	0.05110558	0.09530539	0.08713419
Knowledge Application Structure	0.09174375	0.09766281	0.06200836	0.08705050	0.09218873	0.07555262	0.08842612	0.09329414	0.07915144	0.11108287	0.06010617	0.11919556
Knowledge Application Culture	0.06444119	0.07174267	0.12553242	0.06313140	0.06871263	0.08748046	0.05392464	0.06351916	0.07277289	0.09758347	0.10436037	0.05344217
	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000

Table 4
The stable matrix of ANP when $\lim_{h\to\infty} W^h, h\to\infty$ (ANP) (banking industry).

W^1000	0.07647990	0.07647990	0.07647990	0.07647990	0.07647990	0.07647990	0.07647990	0.07647990	0.07647990	0.07647990	0.07647990	0.07647990
	0.09092040	0.09092040	0.09092040	0.09092040	0.09092040	0.09092040	0.09092040	0.09092040	0.09092040	0.09092040	0.09092040	0.09092040
	0.08221000	0.08221000	0.08221000	0.08221000	0.08221000	0.08221000	0.08221000	0.08221000	0.08221000	0.08221000	0.08221000	0.08221000
	0.07980600	0.07980600	0.07980600	0.07980600	0.07980600	0.07980600	0.07980600	0.07980600	0.07980600	0.07980600	0.07980600	0.07980600
	0.08940720	0.08940720	0.08940720	0.08940720	0.08940720	0.08940720	0.08940720	0.08940720	0.08940720	0.08940720	0.08940720	0.08940720
	0.09168080	0.09168080	0.09168080	0.09168080	0.09168080	0.09168080	0.09168080	0.09168080	0.09168080	0.09168080	0.09168080	0.09168080
	0.07363880	0.07363880	0.07363880	0.07363880	0.07363880	0.07363880	0.07363880	0.07363880	0.07363880	0.07363880	0.07363880	0.07363880
	0.08637770	0.08637770	0.08637770	0.08637770	0.08637770	0.08637770	0.08637770	0.08637770	0.08637770	0.08637770	0.08637770	0.08637770
	0.09473890	0.09473890	0.09473890	0.09473890	0.09473890	0.09473890	0.09473890	0.09473890	0.09473890	0.09473890	0.09473890	0.09473890
	0.06990690	0.06990690	0.06990690	0.06990690	0.06990690	0.06990690	0.06990690	0.06990690	0.06990690	0.06990690	0.06990690	0.06990690
	0.08742580	0.08742580	0.08742580	0.08742580	0.08742580	0.08742580	0.08742580	0.08742580	0.08742580	0.08742580	0.08742580	0.08742580
	0.07740770	0.07740770	0.07740770	0.07740770	0.07740770	0.07740770	0.07740770	0.07740770	0.07740770	0.07740770	0.07740770	0.07740770
	1.00000010	1.00000010	1.00000010	1.00000010	1.00000010	1.00000010	1.00000010	1.00000010	1.00000010	1.00000010	1.00000010	1.00000010

banking industry by the weighting preferences of domain experts in the banking industry. This is true for the assessing of KMC capability for the service industry and the IC (Integrated Circuit) industry.

7. The research findings and managerial implications

The empirical results were discussed as follows. In the first place, the most important criteria calculated by ANP when making adopting KM components decisions were Knowledge STorage Culture (weighting 0.0947) for banking industry, Knowledge SHaring Culture (weighting 0.0956) for IC (Integrated Circuit) industry, and Knowledge SHaring Structure (weighting 0.0963) for service industry.

The Knowledge STorage Culture is most critical for knowledge management adoption of banking industry. The more popular the joining of Knowledge STorage Culture, the better the successful Knowledge Management is. But the preferences of emphasizing on knowledge management components are different. Moreover, the performances of knowledge management components (KMC) in these three industries differ separately. The highest score of KMC in IC (Integrated Circuit) industry is in knowledge storage (3.3733), in addition, the Knowledge STorage Structure (3.5750) gets the highest score among 12 criteria. The highest score of KMC in the banking industry is in knowledge application (3.6086), and the Knowledge Application Structure (3.6719) gets the highest score among 12 criteria. The highest score of KMC in services industry is in knowledge creation (2.8476), and the Knowledge Creation Culture (3.0536) gets the highest score among 12 criteria.

7.1. Research findings

We discovered that the weighting preferences among experts and raters in different industry sectors are quite different; therefore, we should invite the specific domain experts or SME consultants to provide the respective industry weighting. Moreover, the performance of KMCs in industry should be rated/assessed by SME (Small and Medium sized Enterprises) executives because of their experience and understanding of their specific industry domain knowledge.

The findings showed the rankings of knowledge management gaps and performance of knowledge management components in these three industries. The knowledge management gaps of service industry are higher than the gaps of IC (Integrated Circuit) industry and banking industry (Table 7). After normalization and computation, the knowledge management gap of service industry is 0.4399(1), the knowledge management gap of IC (Integrated Circuit) industry is 0.3651(2), and the knowledge management gap of banking industry is 0.2820(3). After the completion of rating for performance of knowledge management components, the knowledge management performance of service industry is 2.8006 (rank 3), the knowledge management performance of IC (Integrated Circuit) industry is 3.1715 (rank 2), and the knowledge management gap of banking industry is 3.5899 (rank 1).

The compromise ranking by VIKOR showed that the bottleneck components of Knowledge Management for banking industry are both Knowledge Application Technology component (0.2969) and

Table 5
The weights of criteria for assessing 3 industries maturity and Total Performance (SAW Method) while using the same weighting preference from banking industry.

Dimensions/criteria	Local weight	Global weight (by ANP)	Perform. of IC industry (A_1)	Perform. of banking (A_2)	Perform. of services (A_3)
Knowledge Creation (D_1)	**0.2496**		**2.9673**	**3.5872**	**2.8476**
K.C. Technology	0.3064	0.0765(10)	2.9136	3.5556	2.6383
K.C. Structure	0.3642	0.0909(3)	3.2639	3.5938	2.8374
K.C. Culture	0.3294	0.0822(7)	2.6892	3.6094	3.0536
Knowledge Sharing (D_2)	**0.2609**		**3.0702**	**3.5833**	**2.8157**
K.Sh. Technology	0.3059	0.0798(8)	3.1852	3.6111	2.7295
K.Sh. Structure	0.3427	0.0894(4)	3.1250	3.5156	2.8889
K.Sh. Culture	0.3514	0.0917(2)	2.9167	3.6250	2.8194
Knowledge Storage (D_3)	**0.2548**		**3.4271**	**3.5826**	**2.8268**
K.St. Technology	0.2891	0.0736(11)	3.5000	3.5625	2.5972
K.St. Structure	0.3391	0.0864(6)	3.5750	3.5216	2.8634
K.St. Culture	0.3719	0.0947(1)	3.2346	3.6528	2.9712
Knowledge Application (D_4)	**0.2347**		**3.2236**	**3.6086**	**2.7307**
K.A. Technology	0.2978	0.0699(12)	3.1389	3.5156	2.5926
K.A. Structure	0.3724	0.0874(5)	3.3472	3.6719	2.6574
K.A. Culture	0.3298	0.0774(9)	3.1605	3.6210	2.9383
Total Performance			**3.1715(2)**	**3.5900(1)**	**2.8065 (3)**

Example:
Calculating Total Performance by global weights: 0.0765*2.9136+0.0909*3.2639+0.0822*2.6892+0.0798*3.1852+0.0894*3.1250+0.0917*2.9167+0.0736*3.5000+0.0864*3.5750+0.0947*3.2346+0.0699*3.1389+0.0874*3.3472+0.0774*3.1605=3.1715.
Calculating Total Performance by local weights:
0.2496*2.9673+0.2609*3.0702+0.2548*3.4271+0.2347*3.2236=3.1715.

Table 6
The weights of criteria for assessing 3 industries maturity and Total Performance (VIKOR method) while using the same weighting preference from banking industry.

Dimensions/criteria	Local weight	Global weight (by ANP) banking	Gaps of IC industry (A_1)	Gaps of banking (A_2)	Gaps of services (A_3)
Knowledge Creation (D_1)	**0.2496**		**0.4065**	**0.2826**	**0.4305**
K.C. Technology	0.3064	0.0765(10)	0.4173	0.2889	0.4723
K.C. Structure	0.3642	0.0909(3)	0.3472	0.2812	0.4325
K.C. Culture	0.3294	0.0822(7)	0.4622	0.2781	0.3893
Knowledge Sharing (D_2)	**0.2609**		**0.3738**	**0.2833**	**0.4369**
K.Sh. Technology	0.3059	0.0798(8)	0.3630	0.2778	0.4541
K.Sh. Structure	0.3427	0.0894(4)	0.3750	0.2969	0.4222
K.Sh. Culture	0.3514	0.0917(2)	0.4167	0.2750	0.4361
Knowledge Storage (D_3)	**0.2548**		**0.3109**	**0.2836**	**0.4347**
K.St. Technology	0.2891	0.0736(11)	0.3000	0.2875	0.4806
K.St. Structure	0.3391	0.0864(6)	0.2850	0.2957	0.4273
K.St. Culture	0.3719	0.0947(1)	0.3531	0.2694	0.4058
Knowledge Application (D_4)	**0.2347**		**0.3553**	**0.2783**	**0.4539**
K.A. Technology	0.2978	0.0699(12)	0.3722	0.2969	0.4815
K.A. Structure	0.3724	0.0874(5)	0.3306	0.2656	0.4685
K.A. Culture	0.3298	0.0774(9)	0.3679	0.2758	0.4123
S_{A_1}	Total gaps		0.3657(2)	0.2820 (1)	0.4387 (3)
Q_{A_1}	Maximal gaps		0.4622(2)	0.2969 (1)	0.4815 (3)

Example:
Calculating dimension gap by dimensions of local weights:

$$S_{D_1} = d_{D_1}^{p=1} = \sum_{i=1}^{3} w_i^{D_1}\left(\frac{f_i^{*D_1} - f_{ik}^{D_1}}{f_j^{*D_1} - f_i^{-D_1}}\right) = 0.3064 \times \left(\frac{5-2.9136}{5-0}\right) + 0.3642 \times \left(\frac{5-3.2639}{5-0}\right) + 0.3294 \times \left(\frac{5-2.6892}{5-0}\right) = 0.4065$$

Calculating total gap by criteria of global weights:

$$S_{A_1} = d_{A_1}^{p=1} = \sum_{i=1}^{8} w_i\left(\frac{f_i^* - f_{iA_1}}{f_i^* - f_i^-}\right) = 0.0765 \times \left(\frac{5-2.9136}{5-0}\right) + 0.0909 \times \left(\frac{5-3.2639}{5-0}\right) + 0.0822 \times \left(\frac{5-2.6892}{5-0}\right) + 0.0798 \times \left(\frac{5-3.1852}{5-0}\right) + 0.0894 \times \left(\frac{5-3.1250}{5-0}\right)$$
$$+ 0.0917 \times \left(\frac{5-2.9167}{5-0}\right) + 0.0736 \times \left(\frac{5-3.5000}{5-0}\right) + 0.0864 \times \left(\frac{5-3.5750}{5-0}\right) + 0.0947 \times \left(\frac{5-3.2346}{5-0}\right) + 0.0699 \times \left(\frac{5-3.1389}{5-0}\right) + 0.0874 \times \left(\frac{5-3.3472}{5-0}\right)$$
$$+ 0.0774 \times \left(\frac{5-3.1605}{5-0}\right) = 0.3657$$

$$Q_{A_1} = d_{A_1}^{p=\infty} = \max\left\{\frac{f_i^* - f_{iA_1}}{f_i^* - f_i^-} \mid i = 1, \ldots, n\right\} = 0.4622$$

Knowledge SHaring Structure component (0.2969). The bottleneck components of Knowledge Management for IC (Integrated Circuit) industry are Knowledge Creation Culture component (0.4622) and Knowledge Creation Technology component (0.4173). This demonstrates that the culture and technology of knowledge creation process are the critical bottleneck for IC (Integrated Circuit) industry. The bottleneck components of Knowledge Management for the service industry are Knowledge Application Technology component (0.4815) and Knowledge STorage Technology component (0.4806). The compromise ranking by VIKOR showed that the best adoption strategy for these three industries are Knowledge Application Technology (order 1) and Knowledge STorage Technology component (order 2) for service industry, Knowledge Creation Culture component (order 1) and Knowledge Creation Technology component (order 2) for IC (Integrated Circuit) industry, and Knowledge Application Technology component (order 1) and Knowledge SHaring Structure component (order 2) for banking industry.

This is why we suggest that the adoption strategy for different industry sectors should be considered separately according to which industry they belonging to SME (Small and Medium sized Enterprises) industry sectors.

Although the adoption strategy and assessment model provided by this study can be used in most of the countries of the world, there are some differences that practitioners should keep in mind when applying this model: the level of importance of the twelve criteria could be varied according to the situations of the country so that practitioners can adopt the most critical knowledge management components that they want to invest in and compare them and then make the optimal investment decision even their small enterprise scaling and lack of capital among the most of SME.

7.2. Conclusion

We have demonstrated that by using the Delphi method and Grounded Theory approach to consolidate the research issues by aggregating suggestion of experts/practitioners including SME consultants, knowledge management domain scholars, and executive managers of SMEs, and by implementing the DEMATEL technique to acquire the structure of Impact-Direction Map of knowledge management components can indeed improve gaps in performance values (Figs. 3–6). The weights of each criterion from the structure were obtained by utilizing the ANP, and the VIKOR technique was leveraged for calculating compromise ranking gaps of the alternatives for improving the priorities of alternatives of portfolios.

We have also found that the weighting preferences among experts and raters differ between industry sectors. Therefore, specific domain experts or SME consultants should be invited to provide that industry adoption weighting. Additionally, the performance of KMCs in each industry should be rated/assessed by SME (Small and Medium sized Enterprises) executives based upon the experiences and understanding of their specific industry domain knowledge.

7.3. Limitations and future works

This study was based on the finding of knowledge management gaps in SMEKM (Knowledge Management Plan for Small and Medium Enterprises) project of Small and Medium Enterprise Administration, Ministry of Economic Affairs, Taiwan. Since banking industry, services industry, and Integrated Circuit industry are three major industries in Taiwan. Most of the data, SME consultants, knowledge management domain scholars, and executive managers of SMEs are all from these

Table 7
The weights, performance, gaps of banking industry (SAW method, VIKOR).

Dimensions/criteria	Local weight	Global weight (by ANP) banking	Perform. of banking industry	Gaps of banking industry
Knowledge Creation (D_1)	**0.2496**		**3.5872**	**0.2826**
K.C. Technology	0.3064	0.0765(10)	3.5556	0.2889
K.C. Structure	0.3642	0.0909(3)	3.5938	0.2812
K.C. Culture	0.3294	0.0822(7)	3.6094	0.2781
Knowledge Sharing (D_2)	**0.2609**		**3.5833**	**0.2833**
K.Sh. Technology	0.3059	0.0798(8)	3.6111	0.2778
K.Sh. Structure	0.3427	0.0894(4)	3.5156	0.2969
K.Sh. Culture	0.3514	0.0917(2)	3.6250	0.2750
Knowledge Storage (D_3)	**0.2548**		**3.5826**	**0.2836**
K.St. Technology	0.2891	0.0736(11)	3.5625	0.2875
K.St. Structure	0.3391	0.0864(6)	3.5216	0.2957
K.St. Culture	0.3719	0.0947(1)	3.6528	0.2694
Knowledge Application (D_4)	**0.2347**		**3.6086**	**0.2783**
K.A. Technology	0.2978	0.0699(12)	3.5156	0.2969
K.A. Structure	0.3724	0.0874(5)	3.6719	0.2656
K.A. Culture	0.3298	0.0774(9)	3.6210	0.2758
Total Performance			**3.5899(1)**	0.2826 (1) 0.2969(3)

Example:
Calculating Total Performance by global weights: 0.0765*3.5556+0.0909*3.5938+0.0822*3.6094+0.0798*3.6111+0.0894*3.5156+0.0917*3.6250+0.0736*3.5625+0.0864*3.5216+0.0947*3.6528+0.0699*3.5156+0.0874*3.6719+0.0774*3.6210=3.5899.
Calculating Total Performance by local weights:
0.2496*3.5872+0.2609*3.5833+0.2548*3.5826+0.2347*3.6086=3.5900.
Calculating dimension gap by dimensions of local weights:

$$S_{D_1}=d_{D_1}^{p=1}=\sum_{i=1}^{3}w_j^{D_1}\left(\frac{f_i^{*D_1}-f_{ik}^{D_1}}{f_i^{*D_1}-f_i^{-}}\right)=0.3064\times\left(\frac{5-3.5556}{5-0}\right)+0.3642\times\left(\frac{5-3.5938}{5-0}\right)+0.3294\times\left(\frac{5-3.6094}{5-0}\right)=0.2826$$

Calculating total gap by criteria of global weights:

$$S_{A_1}=d_{A_1}^{p=1}=\sum_{i=1}^{8}w_i\left(\frac{f_i^{*}-f_{iA_1}}{f_i^{*}-f_i^{-}}\right)=0.0765\times\left(\frac{5-3.5556}{5-0}\right)+0.0909\times\left(\frac{5-3.5938}{5-0}\right)+0.0822\times\left(\frac{5-3.6094}{5-0}\right)+0.0798\times\left(\frac{5-3.6111}{5-0}\right)+0.0894\times\left(\frac{5-3.5156}{5-0}\right)$$

$$+0.0917\times\left(\frac{5-3.6250}{5-0}\right)+0.0736\times\left(\frac{5-3.5625}{5-0}\right)+0.0864\times\left(\frac{5-3.5216}{5-0}\right)+0.0947\times\left(\frac{5-3.6528}{5-0}\right)+0.0699\times\left(\frac{5-3.5156}{5-0}\right)+0.0874\times\left(\frac{5-3.6719}{5-0}\right)$$

$$+0.0774\times\left(\frac{5-3.6210}{5-0}\right)=0.2820$$

$$Q_{A_1}=d_{A_1}^{p=\infty}=\max\left\{\frac{f_i^{*}-f_{iA_1}}{f_i^{*}-f_i^{-}}\,|\,i=1,\ \ldots,n\right\}=0.2969$$

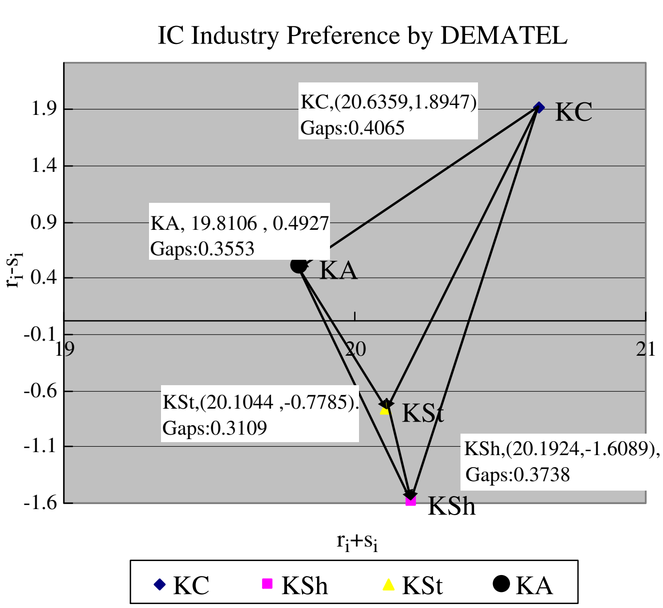


Fig. 3. The Impact-Direction Map for improving gaps in IC (Integrated Circuit) industry.

three industries because of the resources accessibility. The data were also collected from the EMBA students, and most of these EMBA students were from these three industries. Therefore, we choose these three industries as targets of this study. This is the limitation of the study. Moreover, as previously mentioned specific countries may have specific requirements of their knowledge management solutions and our study was solely the lesson learned from Taiwanese managers.

Our future work should focus on two issues: our knowledge management adoption and assessment strategies were based on the KM staged model, which inherit the spirit of CMMI (Capability Maturity Model Integration) staged models. However, sometimes knowledge management processes and components can be well represented and managed by knowledge management continuous representation instead of knowledge management staged representation. Therefore, we suggest that we should revise the KMMM (Knowledge Management Maturity Model) template and further discuss further the usability and reliability for the Multiple Criteria Decision Making on continuous knowledge management representation.

Second, we should deal with the qualitative assessment issues, such as the subjective judgment of the experts' perception. This is especially true when we need to determine the weights of decision criteria for each relative interest group, including the owners', users', and experts' subjective perceptions in any future work. We can facilitate this through Fuzzy Analytic Network Process (FANP) to determine the weights of decision criteria for each expert group. Then the Fuzzy Multiple Criteria Decision Making (FMCDM) approach can be used to synthesize the

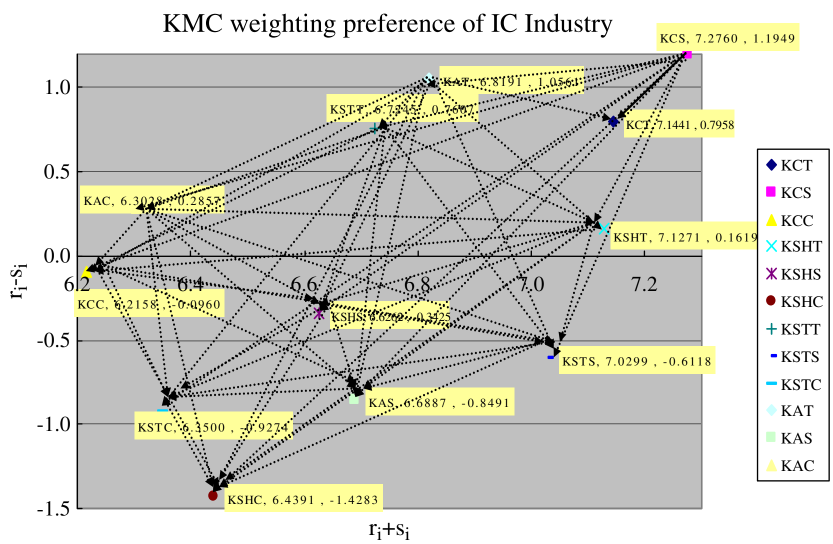


Fig. 4. The Impact-Direction Map of KMCs for improving gaps (Integrated Circuit industry).

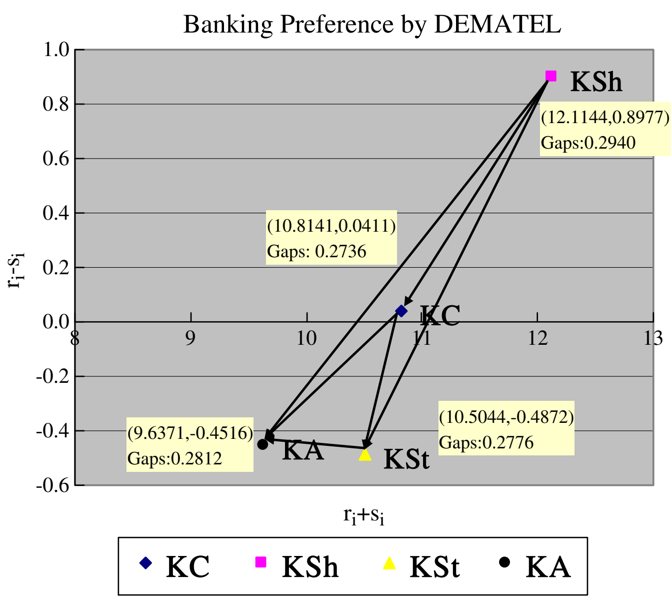


Fig. 5. The Impact-Direction Map for improving gaps in performance values (banking industry).

group decision. This process might enable decision makers to formalize and effectively solve the complicated, multi-criteria, and fuzzy/vague perception problems for most of the appropriate strategies in knowledge management alternative adoption. From the criteria weights of industry-specific domain expert groups by Fuzzy ANP and the average fuzzy performance values of each criterion from SME (Small and Medium sized Enterprises) practitioners for each alternative, then the final fuzzy synthetic decision can then be processed.

Appendix A. VIKOR for emergent unimproved gaps

In this example, the organization fulfills all the requirements of the first stage of KMM (i.e., the initial stage), but some KM activities do not reach the minimum required threshold of the second KMMM (Knowledge Management Maturity Model) stage. Hence, to progress to the next stage, the organization should focus on these critical KM activities and refine them to meet the threshold criteria. In the figure the gaps highlighted in orange are deemed the most urgent. The breakthrough activities (ivory color) should be maintained, but some of the resources should be used to strengthen and support the urgent KM activities that do not meet the minimum thresholds.

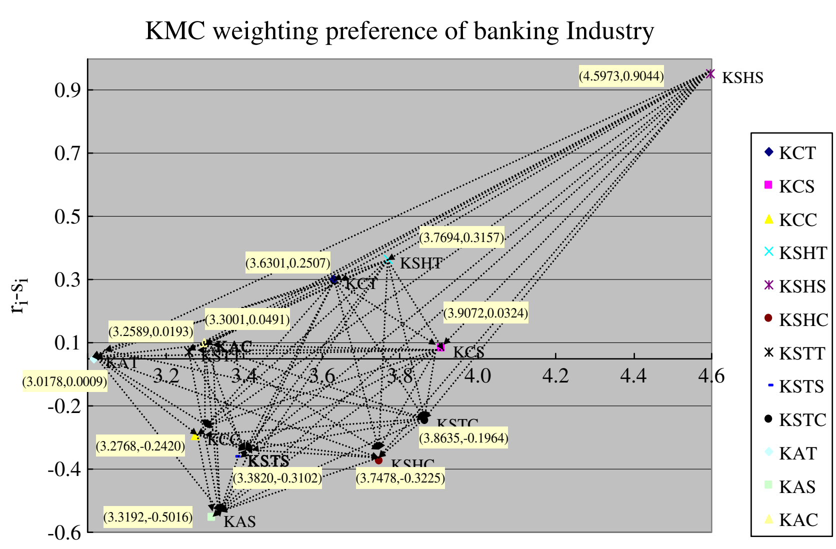


Fig. 6. The Impact-Direction Map for improving gaps in performance values (banking industry).

Appendix A1. VIKOR for emergent unimproved gaps

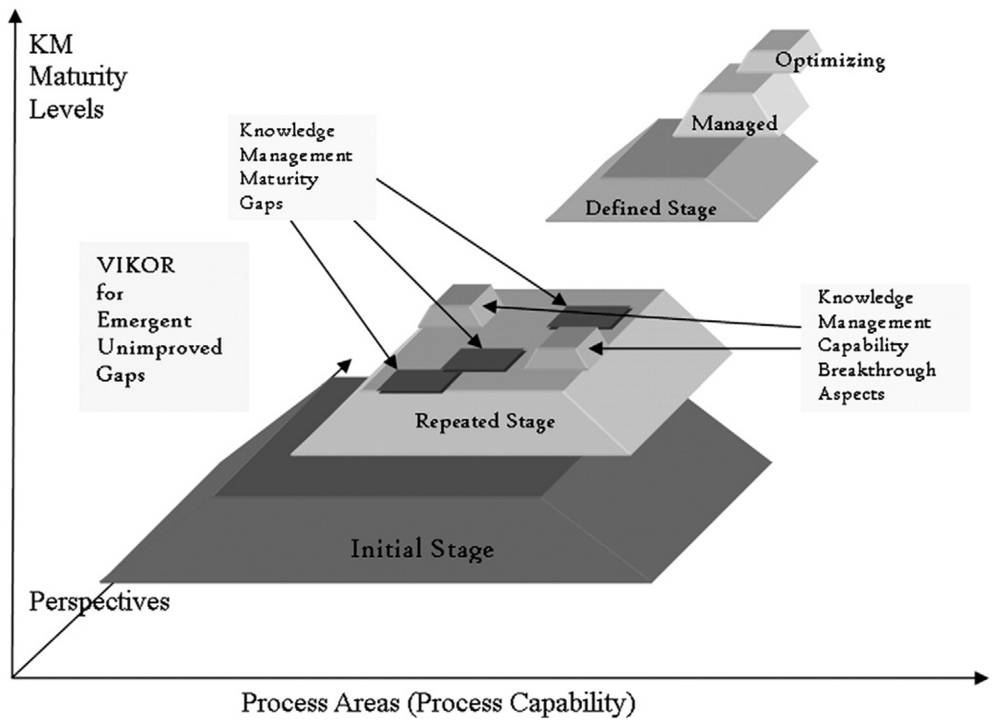


Fig. A1. VIKOR for emergent unimproved gaps.

Appendix A2. An example of examining the current KM capability position

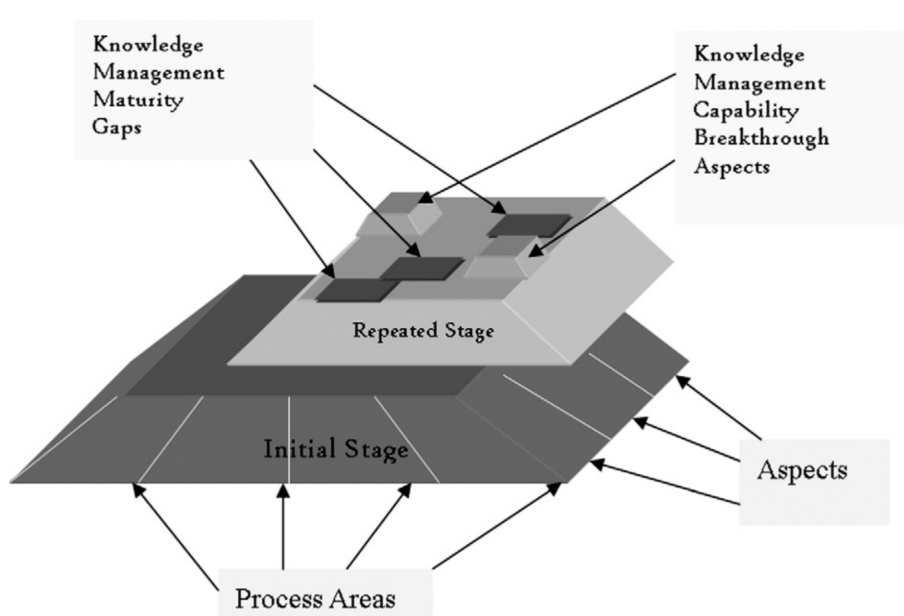


Fig. A2. An example of examining the current KM capability position.

Appendix A3. Complete the weighting by consultants and KMC performance by SME CEO/Rater

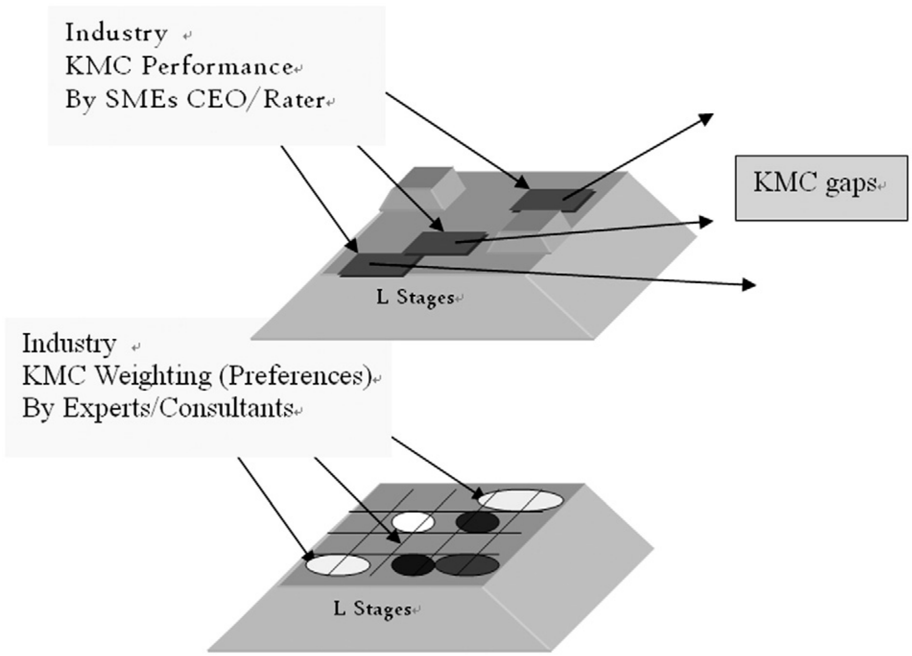


Fig. A3. Complete the weighting by consultants and KMC performance by SME CEO/Rater.

Appendix B. Demonstrations of the procedures of DEMATEL in banking industry

Appendix B1. The pair-wise influence matrix for KM components was rated by focus group of KM experts

	KCT	KCS	KCC	KSHT	KSHS	KSHC	KSTT	KSTS	KSTC	KAT	KAS	KAC	Row sum	Original	In short
KCT	0	2	1	2	2	1	2	2	1	2	2	1	18	Knowledge Creation Technology	KCT
KCS	3	0	3	1	3	0	1	2	1	1	2	1	18	Knowledge Creation Structure	KCS
KCC	2	3	0	0	0	3	0	0	3	0	0	3	14	Knowledge Creation Culture	KCC
KSHT	3	1	1	0	2	3	2	1	1	2	2	1	19	Knowledge SHaring Technology	KSHT
KSHS	3	3	2	3	0	3	3	2	3	1	2	1	26	Knowledge SHaring Structure	KSHS
KSHC	0	1	2	3	1	0	1	2	2	1	1	2	16	Knowledge SHaring Culture	KSHC
KSTT	2	1	1	3	1	1	0	2	2	1	1	0	15	Knowledge STorage Technology	KSTT
KSTS	0	2	0	0	2	1	2	0	3	1	2	1	14	Knowledge STorage Structure	KSTS
KSTC	0	1	2	2	2	3	2	2	0	1	1	1	17	Knowledge STorage Culture	KSTC
KAT	2	0	0	2	1	1	2	1	1	0	2	2	14	Knowledge Application Technology	KAT
KAS	0	2	2	0	2	1	0	2	0	2	0	2	13	Knowledge Application Structure	KAS
KAC	1	2	2	0	1	2	0	1	2	2	3	0	16	Knowledge Application Culture	KAC
Colum sum	16	18	16	16	17	19	15	17	19	14	18	15			

The degree of influence from KCT to KCT, KCS, KCC, KSHT, KSHS, KSHC, KSTT, KSTS, KSTC, KAT, KAS, and KAC are 0, 2, 1, 2, 2, 1, 2, 2, 1, 2, 2, and 1, respectively.

*Appendix B2. After the normalization of pair-wise influence matrix **X** (Divided by the maximum value of sum of rows/sum of columns.) matrix **X***

	KCT	KCS	KCC	KSHT	KSHS	KSHC	KSTT	KSTS	KSTC	KAT	KAS	KAC
KCT	0	0.07692	0.03846	0.07692	0.07692	0.03846	0.07692	0.07692	0.03846	0.07692	0.07692	0.03846
KCS	0.11538	0	0.11538	0.03846	0.11538	0	0.03846	0.07692	0.03846	0.03846	0.07692	0.03846
KCC	0.07692	0.11538	0	0	0	0.11538	0	0	0.11538	0	0	0.11538
KSHT	0.11538	0.03846	0.03846	0	0.07692	0.11538	0.07692	0.03846	0.03846	0.07692	0.07692	0.03846
KSHS	0.11538	0.11538	0.07692	0.11538	0	0.11538	0.11538	0.07692	0.11538	0.03846	0.07692	0.03846
KSHC	0	0.03846	0.07692	0.11538	0.03846	0	0.03846	0.07692	0.07692	0.03846	0.03846	0.07692
KSTT	0.07692	0.03846	0.03846	0.11538	0.03846	0.03846	0	0.07692	0.07692	0.03846	0.03846	0
KSTS	0	0.07692	0	0	0.07692	0.03846	0.07692	0	0.11538	0.03846	0.07692	0.03846
KSTC	0	0.03846	0.07692	0.07692	0.07692	0.11538	0.07692	0.07692	0	0.03846	0.03846	0.03846
KAT	0.07692	0	0	0.07692	0.03846	0.03846	0.07692	0.03846	0.03846	0	0.07692	0.07692
KAS	0	0.07692	0.07692	0	0.07692	0.03846	0	0.07692	0	0.07692	0	0.07692
KAC	0.03846	0.07692	0.07692	0	0.03846	0.07692	0	0.03846	0.07692	0.07692	0.11538	0

I

	I	I	I	I	I	I	I	I	I	I	I	I
I	1	0	0	0	0	0	0	0	0	0	0	0
I	0	1	0	0	0	0	0	0	0	0	0	0
I	0	0	1	0	0	0	0	0	0	0	0	0
I	0	0	0	1	0	0	0	0	0	0	0	0
I	0	0	0	0	1	0	0	0	0	0	0	0
I	0	0	0	0	0	1	0	0	0	0	0	0
I	0	0	0	0	0	0	1	0	0	0	0	0
I	0	0	0	0	0	0	0	1	0	0	0	0
I	0	0	0	0	0	0	0	0	1	0	0	0
I	0	0	0	0	0	0	0	0	0	1	0	0
I	0	0	0	0	0	0	0	0	0	0	1	0
I	0	0	0	0	0	0	0	0	0	0	0	1

I–X

1	−0.077	−0.038	−0.077	−0.077	−0.038	−0.077	−0.077	−0.038	−0.077	−0.077	−0.038
−0.1154	1	−0.1154	−0.0385	−0.1154	0	−0.0385	−0.0769	−0.0385	−0.0385	−0.0769	−0.0385
−0.0769	−0.1154	1	0	0	−0.1154	0	0	−0.1154	0	0	−0.1154
−0.1154	−0.0385	−0.0385	1	−0.0769	−0.1154	−0.0769	−0.0385	−0.0385	−0.0769	−0.0769	−0.0385
−0.1154	−0.1154	−0.0769	−0.1154	1	−0.1154	−0.1154	−0.0769	−0.1154	−0.0385	−0.0769	−0.0385
0	−0.0385	−0.0769	−0.1154	−0.0385	1	−0.0385	−0.0769	−0.0769	−0.0385	−0.0385	−0.0769
−0.0769	−0.0385	−0.0385	−0.1154	−0.0385	−0.0385	1	−0.0769	−0.0769	−0.0385	−0.0385	0
0	−0.0769	0	0	−0.0769	−0.0385	−0.0769	1	−0.1154	−0.0385	−0.0769	−0.0385
0	−0.0385	−0.0769	−0.0769	−0.0769	−0.1154	−0.0769	−0.0769	1	−0.0385	−0.0385	−0.0385
−0.0769	0	0	−0.0769	−0.0385	−0.0385	−0.0769	−0.0385	−0.0385	1	−0.0769	−0.0769
0	−0.0769	−0.0769	0	−0.0769	−0.0385	0	−0.0769	0	−0.0769	1	−0.0769
−0.0385	−0.0769	−0.0769	0	−0.0385	−0.0769	0	−0.0385	−0.0769	−0.0769	−0.1154	1

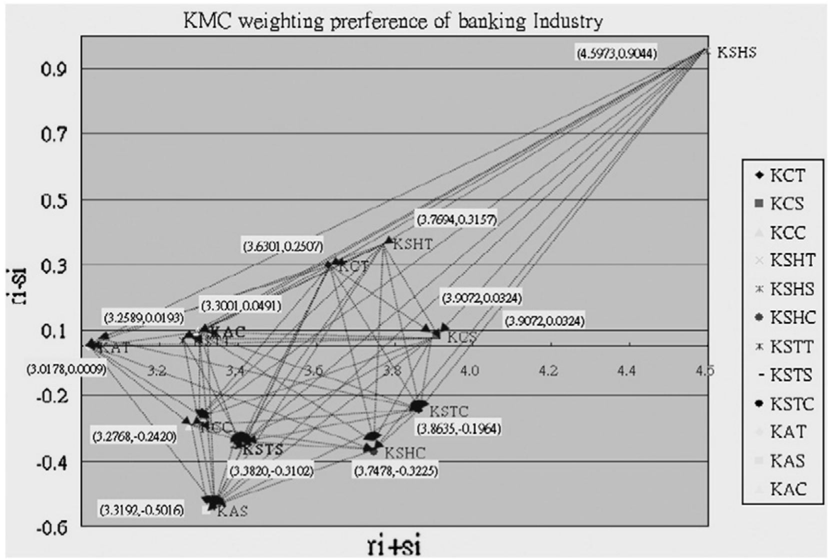
Inverse(***I–X***)

1.1047	0.1864	0.1401	0.1758	0.1845	0.1555	0.1716	0.1832	0.1566	0.1630	0.1874	0.1317
0.2130	1.1268	0.2128	0.1378	0.2183	0.1276	0.1368	0.1826	0.1634	0.1271	0.1865	0.1370
0.1447	0.1972	1.0933	0.0815	0.0899	0.2014	0.0709	0.0897	0.2011	0.0714	0.0914	0.1851
0.2116	0.1570	0.1460	1.1163	0.1870	0.2314	0.1761	0.1560	0.1621	0.1687	0.1915	0.1389
0.2496	0.2678	0.2224	0.2574	1.1595	0.2772	0.2454	0.2309	0.2756	0.1643	0.2296	0.1712
0.0906	0.1386	0.1642	0.1930	0.1331	1.1139	0.1209	0.1653	0.1813	0.1158	0.1371	0.1588
0.1583	0.1323	0.1217	0.1967	0.1336	0.1421	1.0881	0.1658	0.1726	0.1143	0.1326	0.0809
0.0785	0.1621	0.0900	0.0874	0.1627	0.1321	0.1506	1.0924	0.2021	0.1068	0.1613	0.1098
0.0966	0.1461	0.1711	0.1732	0.1726	0.2256	0.1637	0.1751	1.1203	0.1186	0.1409	0.1295
0.1482	0.0897	0.0807	0.1537	0.1232	0.1308	0.1480	0.1244	0.1268	1.0755	0.1641	0.1442
0.0767	0.1604	0.1499	0.0692	0.1502	0.1231	0.0686	0.1488	0.0948	0.1347	1.0850	0.1475
0.1173	0.1729	0.1672	0.0849	0.1320	0.1743	0.0790	0.1318	0.1733	0.1483	0.2028	1.0909

$\boldsymbol{T} = \boldsymbol{X}$* Inverse(***I–X***)

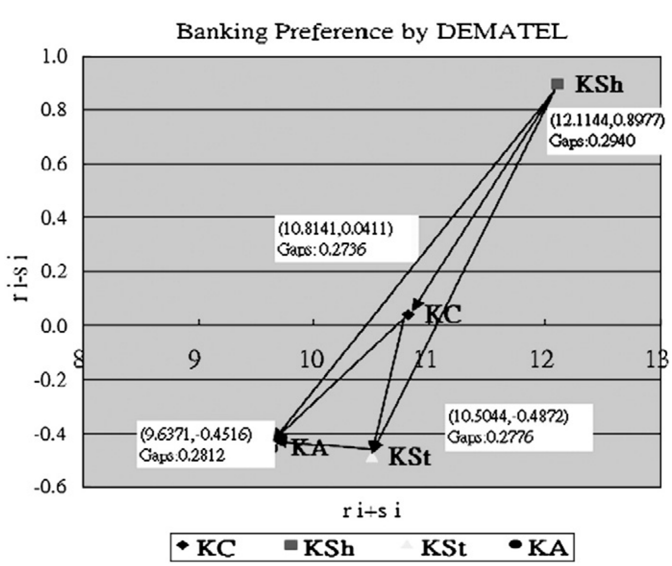
	KCT	KCS	KCC	KSHT	KSHS	KSHC	KSTT	KSTS	KSTC	KAT	KAS	KAC	$\boldsymbol{r}_i$
KCT	0.1047	0.1864	0.1401	0.1758	0.1845	0.1555	0.1716	0.1832	0.1566	0.1630	0.1874	0.1317	1.9404
KCS	0.2130	0.1268	0.2128	0.1378	0.2183	0.1276	0.1368	0.1826	0.1634	0.1271	0.1865	0.1370	1.9698
KCC	0.1447	0.1972	0.0933	0.0815	0.0899	0.2014	0.0709	0.0897	0.2011	0.0714	0.0914	0.1851	1.5174
KSHT	0.2116	0.1570	0.1460	0.1163	0.1870	0.2314	0.1761	0.1560	0.1621	0.1687	0.1915	0.1389	2.0426
KSHS	0.2496	0.2678	0.2224	0.2574	0.1595	0.2772	0.2454	0.2309	0.2756	0.1643	0.2296	0.1712	2.7509
KSHC	0.0906	0.1386	0.1642	0.1930	0.1331	0.1139	0.1209	0.1653	0.1813	0.1158	0.1371	0.1588	1.7126
KSTT	0.1583	0.1323	0.1217	0.1967	0.1336	0.1421	0.0881	0.1658	0.1726	0.1143	0.1326	0.0809	1.6391
KSTS	0.0785	0.1621	0.0900	0.0874	0.1627	0.1321	0.1506	0.0924	0.2021	0.1068	0.1613	0.1098	1.5359
KSTC	0.0966	0.1461	0.1711	0.1732	0.1726	0.2256	0.1637	0.1751	0.1203	0.1186	0.1409	0.1295	1.8335
KAT	0.1482	0.0897	0.0807	0.1537	0.1232	0.1308	0.1480	0.1244	0.1268	0.0755	0.1641	0.1442	1.5094
KAS	0.0767	0.1604	0.1499	0.0692	0.1502	0.1231	0.0686	0.1488	0.0948	0.1347	0.0850	0.1475	1.4088
KAC	0.1173	0.1729	0.1672	0.0849	0.1320	0.1743	0.0790	0.1318	0.1733	0.1483	0.2028	0.0909	1.6746
si	1.6897	1.9374	1.7594	1.7268	1.8464	2.0351	1.6198	1.8461	2.0300	1.5084	1.9104	1.6255	

Appendix B3. The Impact-irection Map for improving gaps in performance values (banking industry)



	r_i	s_i	r_i+s_i	r_i-s_i
KCT	1.9404	1.6897	3.6301	0.2507
KCS	1.9698	1.9374	3.9072	0.0324
KCC	1.5174	1.7594	3.2768	−0.2420
KSHT	2.0426	1.7268	3.7694	0.3157
KSHS	2.7509	1.8464	4.5973	0.9044
KSHC	1.7126	2.0351	3.7478	−0.3225
KSTT	1.6391	1.6198	3.2589	0.0193
KSTS	1.5359	1.8461	3.3820	−0.3102
KSTC	1.8335	2.0300	3.8635	−0.1964
KAT	1.5094	1.5084	3.0178	0.0009
KAS	1.4088	1.9104	3.3192	−0.5016
KAC	1.6746	1.6255	3.3001	0.0491

Appendix B4. The Impact-irection Map for improving gaps in performance values (banking industry) from process perspectives



	KC	KSh	KSt	KA	r_i
KC	1.4190	1.3721	1.3559	1.2806	5.4276
KSh	1.6478	1.6688	1.7135	1.4760	6.5061
KSt	1.1568	1.4261	1.3309	1.0947	5.0086
KA	1.1628	1.1413	1.0955	1.1931	4.5928
si	5.3865	5.6084	5.4958	5.0444	

	r_i	s_i	r_i+s_i	r_i-s_i
KC	5.4276	5.3865	10.8141	0.0411
KSH	6.5061	5.6084	12.1144	0.8977
KST	5.0086	5.4958	10.5044	−0.4872
KA	4.5928	5.0444	9.6371	−0.4516

Appendix C. Procedures of finding global weighting by ANP

Table C1
Total matrix ***T***.

0.1047	0.1864	0.1401	0.1758	0.1845	0.1555	0.1716	0.1832	0.1566	0.1630	0.1874	0.1317
0.2130	0.1268	0.2128	0.1378	0.2183	0.1276	0.1368	0.1826	0.1634	0.1271	0.1865	0.1370
0.1447	0.1972	0.0933	0.0815	0.0899	0.2014	0.0709	0.0897	0.2011	0.0714	0.0914	0.1851
0.2116	0.1570	0.1460	0.1163	0.1870	0.2314	0.1761	0.1560	0.1621	0.1687	0.1915	0.1389
0.2496	0.2678	0.2224	0.2574	0.1595	0.2772	0.2454	0.2309	0.2756	0.1643	0.2296	0.1712
0.0906	0.1386	0.1642	0.1930	0.1331	0.1139	0.1209	0.1653	0.1813	0.1158	0.1371	0.1588
0.1583	0.1323	0.1217	0.1967	0.1336	0.1421	0.0881	0.1658	0.1726	0.1143	0.1326	0.0809
0.0785	0.1621	0.0900	0.0874	0.1627	0.1321	0.1506	0.0924	0.2021	0.1068	0.1613	0.1098
0.0966	0.1461	0.1711	0.1732	0.1726	0.2256	0.1637	0.1751	0.1203	0.1186	0.1409	0.1295
0.1482	0.0897	0.0807	0.1537	0.1232	0.1308	0.1480	0.1244	0.1268	0.0755	0.1641	0.1442
0.0767	0.1604	0.1499	0.0692	0.1502	0.1231	0.0686	0.1488	0.0948	0.1347	0.0850	0.1475
0.1173	0.1729	0.1672	0.0849	0.1320	0.1743	0.0790	0.1318	0.1733	0.1483	0.2028	0.0909

	KC	KSH	KST	KAC	
KC	1.4190	1.3721	1.3559	1.2806	5.4276
KSH	1.6478	1.6688	1.7135	1.4760	6.5061
KST	1.1568	1.4261	1.3309	1.0947	5.0086
KAC	1.1628	1.1413	1.0955	1.1931	4.5928
	5.3865	5.6084	5.4958	5.0444	

t11	t12	t13	t14	t1
t21	t22	t23	t24	t2
t31	t32	t33	t34	t3
t41	t42	t43	t44	t4

Table C2
Unweighted matrix ***W***.

	KCT	KCS	KCC	KSHT	KSHS	KSHC	KSTT	KSTS	KSTC	KAT	KAS	KAC
KCT	0.2427	0.3855	0.3325	0.4112	0.3374	0.2302	0.3840	0.2375	0.2335	0.4651	0.1981	0.2564
KCS	0.4324	0.2295	0.4531	0.3050	0.3620	0.3524	0.3209	0.4904	0.3530	0.2816	0.4146	0.3780
KCC	0.3249	0.3851	0.2144	0.2838	0.3006	0.4174	0.2951	0.2722	0.4135	0.2532	0.3873	0.3656
KSHT	0.3408	0.2849	0.2186	0.2176	0.3709	0.4386	0.4164	0.2287	0.3031	0.3840	0.2375	0.2335
KSHS	0.3577	0.4514	0.2412	0.3497	0.2298	0.3025	0.2829	0.4255	0.3021	0.3209	0.4904	0.3530
KSHC	0.3016	0.2638	0.5403	0.4327	0.3993	0.2589	0.3008	0.3457	0.3948	0.2951	0.2722	0.4135
KSTT	0.3356	0.2834	0.1962	0.3563	0.3264	0.2586	0.2066	0.3384	0.3566	0.3706	0.2196	0.2057
KSTS	0.3583	0.3782	0.2479	0.3157	0.3071	0.3536	0.3888	0.2076	0.3814	0.3117	0.4766	0.3432
KSTC	0.3062	0.3385	0.5560	0.3279	0.3666	0.3877	0.4046	0.4540	0.2621	0.3177	0.3038	0.4511
KAT	0.3380	0.2820	0.2051	0.3380	0.2908	0.2814	0.3487	0.2825	0.3049	0.1967	0.3669	0.3354
KAS	0.3888	0.4139	0.2628	0.3837	0.4064	0.3330	0.4046	0.4268	0.3621	0.4276	0.2314	0.4588
KAC	0.2731	0.3041	0.5320	0.2783	0.3029	0.3856	0.2467	0.2906	0.3330	0.3757	0.4017	0.2057

Table C2 (*continued*)

Weight				
	0.2614	0.2528	0.2498	0.2359
	0.2533	0.2565	0.2634	0.2269
	0.2310	0.2847	0.2657	0.2186
	0.2532	0.2485	0.2385	0.2598

Table C3
Weighted matrix $\boldsymbol{W}^{\boldsymbol{weighted}}$ by normalization.

	KCT	KCS	KCC	KSHT	KSHS	KSHC	KSTT	KSTS	KSTC	KAT	KAS	KAC
KCT	0.06345620	0.10077795	0.08692885	0.10414359	0.08544691	0.05830946	0.08869009	0.05485304	0.05392349	0.11776410	0.05015476	0.06492572
KCS	0.11304172	0.05999107	0.11845530	0.07725408	0.09169038	0.08925526	0.07412048	0.11325413	0.08153067	0.07131082	0.10497532	0.09571033
KCC	0.08495168	0.10068059	0.05606545	0.07187047	0.07613085	0.10570342	0.06815391	0.06285731	0.09551033	0.06411628	0.09806112	0.09255514
KSHT	0.08614570	0.07201157	0.05525401	0.05581322	0.09512415	0.11250879	0.11855249	0.06513007	0.08630336	0.09542590	0.05901901	0.05801885
KSHS	0.09041978	0.11410316	0.06096366	0.08968982	0.05894947	0.07757949	0.08054046	0.12116961	0.08601445	0.07974976	0.12185552	0.08772273
KSHC	0.07623523	0.06668598	0.13658304	0.11099749	0.10242691	0.06641225	0.08564541	0.09843867	0.11242055	0.07333005	0.06763118	0.10276412
KSTT	0.08382554	0.07078848	0.04900293	0.09384944	0.08595311	0.06811593	0.05489448	0.08991790	0.09475343	0.08840888	0.05237778	0.04906488
KSTS	0.08950142	0.09446741	0.06192273	0.08315777	0.08087607	0.09313759	0.10330958	0.05516700	0.10133690	0.07433969	0.11369118	0.08186347
KSTC	0.07648150	0.08455257	0.13888280	0.08636249	0.09654052	0.10211617	0.10752563	0.12064480	0.06963936	0.07578261	0.07246222	0.10760283
KAT	0.07975629	0.06653576	0.04840045	0.07667973	0.06596026	0.06382855	0.07621670	0.06175417	0.06664314	0.05110558	0.09530539	0.08713419
KAS	0.09174375	0.09766281	0.06200836	0.08705050	0.09218873	0.07555262	0.08842612	0.09329414	0.07915144	0.11108287	0.06010617	0.11919556
KAC	0.06444119	0.07174267	0.12553242	0.06313140	0.06871263	0.08748046	0.05392464	0.06351916	0.07277289	0.09758347	0.10436037	0.05344217
	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000

Table C4
ANP matrix $\boldsymbol{W}^{*}$.

W^1000	KCT	KCS	KCC	KSHT	KSHS	KSHC	KSTT	KSTS	KSTC	KAT	KAS	KAC
KCT	0.07647990	0.07647990	0.07647990	0.07647990	0.07647990	0.07647990	0.07647990	0.07647990	0.07647990	0.07647990	0.07647990	0.07647990
KCS	0.09092040	0.09092040	0.09092040	0.09092040	0.09092040	0.09092040	0.09092040	0.09092040	0.09092040	0.09092040	0.09092040	0.09092040
KCC	0.08221000	0.08221000	0.08221000	0.08221000	0.08221000	0.08221000	0.08221000	0.08221000	0.08221000	0.08221000	0.08221000	0.08221000
KSHT	0.07980600	0.07980600	0.07980600	0.07980600	0.07980600	0.07980600	0.07980600	0.07980600	0.07980600	0.07980600	0.07980600	0.07980600
KSHS	0.08940720	0.08940720	0.08940720	0.08940720	0.08940720	0.08940720	0.08940720	0.08940720	0.08940720	0.08940720	0.08940720	0.08940720
KSHC	0.09168080	0.09168080	0.09168080	0.09168080	0.09168080	0.09168080	0.09168080	0.09168080	0.09168080	0.09168080	0.09168080	0.09168080
KSTT	0.07363880	0.07363880	0.07363880	0.07363880	0.07363880	0.07363880	0.07363880	0.07363880	0.07363880	0.07363880	0.07363880	0.07363880
KSTS	0.08637770	0.08637770	0.08637770	0.08637770	0.08637770	0.08637770	0.08637770	0.08637770	0.08637770	0.08637770	0.08637770	0.08637770
KSTC	0.09473890	0.09473890	0.09473890	0.09473890	0.09473890	0.09473890	0.09473890	0.09473890	0.09473890	0.09473890	0.09473890	0.09473890
KAT	0.06990690	0.06990690	0.06990690	0.06990690	0.06990690	0.06990690	0.06990690	0.06990690	0.06990690	0.06990690	0.06990690	0.06990690
KAS	0.08742580	0.08742580	0.08742580	0.08742580	0.08742580	0.08742580	0.08742580	0.08742580	0.08742580	0.08742580	0.08742580	0.08742580
KAC	0.07740770	0.07740770	0.07740770	0.07740770	0.07740770	0.07740770	0.07740770	0.07740770	0.07740770	0.07740770	0.07740770	0.07740770
	1.00000010	1.00000010	1.00000010	1.00000010	1.00000010	1.00000010	1.00000010	1.00000010	1.00000010	1.00000010	1.00000010	1.00000010

Note: Matrix $\boldsymbol{W}^{*}$ multiplies with itself 1000 times, i.e. $\boldsymbol{W}^{*} = \boldsymbol{W}^{1000}$.
The matrix $\boldsymbol{W}^{*}$ is convergent to a stable matrix. These values used to be the weighting values within banking industry. The stable matrix of ANP when $\lim_{h\to\infty} W^h$, $h\to\infty$ (ANP).

Banking	Industry
KCT	0.0765
KCS	0.0909
KCC	0.0822
KSHT	0.0798
KSHS	0.0894
KSHC	0.0917
KSTT	0.0736
KSTS	0.0864
KSTC	0.0947
KAT	0.0699
KAS	0.0874
KAC	0.0774

Appendix D. KMMM (Knowledge Management Maturity Model) achievements

Table D
The forty components of KMMM achievements.

Knowledge Management Capability

Knowledge Creation	Knowledge Storage	Knowledge Sharing	Knowledge Application
Brainstorming System	Data Base Systems	Chat rooms ; Video-Conferences	Work flow system
Decision Support System	Expert yellow-pages	Groupware; Communities of practice	Expert systems
Enterprise Information Portal	FAQ (frequently asked questions)	Enterprise information portal	Patent Management Systems
Artificial Intelligence; Business Intelligence	SOP standard operation procedures	Search engine tools	Enterprise information portal
Data Mining; Knowledge discovery tools;	Enterprise information portal	E-learning	Intellectual property management systems
Quantitative measurement of K.C.	Firewall system , Information security system	Expert yellow pages	OLAP , OLTP systems
E-communities of practice	Centralized file management system , different levels of security	On job expert training, Apprentice system; Training centers	Quantitative mechanisms of K Applications
Formal knowledge creation mechanisms and R & D department	Documentation and Externalization	Focus group meetings, workshop, Knowledge Sharing councils;	R&D unit and a decision-making department
Knowledge identify , inventory /auditing mechanism	Quantitative measurement unit of K.S. to assess performance.	Quantitative goals and quantitative mechanisms of Knowledge Sharing Processes	Value-added applications of knowledge intensive skills and work-flows
Inventive and innovative culture	**Knowledge integration, renewal**	**Learning and sharing culture**	**Applying and value-adding knowledge culture**

Technological component
Structural Component
Cultural

Appendix D1. Components of KM capability

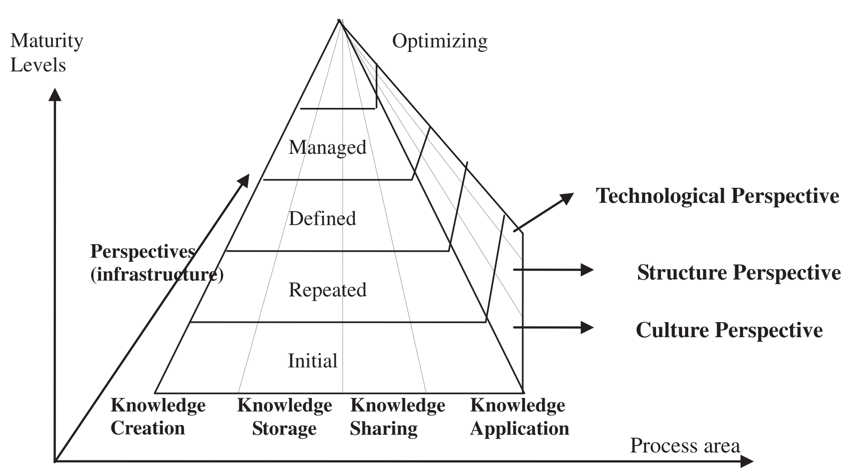


Fig. D1. Components of KM capability [12].

Appendix D2. KMMM (Knowledge Management Maturity Model) performance questionnaires for SME&DEL id=orig= CEOs/practitioners

Table D2
KMMM performance questionnaires.

Knowledge Creation Processes in your Organization						
1. Technological capabilities	None	Poor	Fair	Good	Very Good	Excellent
Please rate the effectiveness of the technologies listed below						
Brainstorming systems (software + hardware)	0	1	2	3	4	5
Data mining; text retrieval; knowledge discovery tools	0	1	2	3	4	5
Learning tools; GUI-aided designs	0	1	2	3	4	5
Simulation models; thinking support systems	0	1	2	3	4	5
Concept mapping systems; instance inferencing systems	0	1	2	3	4	5
Collaborative filtering systems; virtual reality	0	1	2	3	4	5
Enterprise information portals; knowledge management systems	0	1	2	3	4	5
Artificial intelligence; business intelligence	0	1	2	3	4	5
Groupware, decision support systems	0	1	2	3	4	5
2 Structural capabilities	None	Poor	Fair	Good	Very Good	Excellent
Please rate the effectiveness of the following mechanisms						
Informal mechanisms, e-communities of practice	0	1	2	3	4	5
Formal knowledge network mechanisms, Internet, Intranet ,Extranet	0	1	2	3	4	5
Formal knowledge creation mechanisms and R & D department	0	1	2	3	4	5
Dedicated KM groups, dedicated project groups	0	1	2	3	4	5
Knowledge identification, knowledge inventory/auditing mechanisms	0	1	2	3	4	5
Quantitative measurement system for KC	0	1	2	3	4	5
Incentive mechanisms to encourage innovation	0	1	2	3	4	5
A dedicated quantitative measurement section to assess performance	0	1	2	3	4	5
	0	1	2	3	4	5
3. Cultural capabilities	None	Poor	Fair	Good	Very Good	Excellent
How effective are the following cultural characteristics within your organization?						
Awareness of the importance of knowledge management	0	1	2	3	4	5
Encouragement of innovation, creativity is valued.	0	1	2	3	4	5
Adventurous – people are willing to attempt novel approaches	0	1	2	3	4	5
Inventive and innovative culture	0	1	2	3	4	5
Diversified cultural context and international outlook	0	1	2	3	4	5
People are encouraged to ask questions and express opinions.	0	1	2	3	4	5
Most people are enthusiastic and spontaneous.	0	1	2	3	4	5
Proactive attitudes.	0	1	2	3	4	5
Positive working atmosphere – staff feel valued	0	1	2	3	4	5

Appendix D3

Table D3
The KMMM (Knowledge Management Maturity Model) surveying table.

Level	Objectives	Practiced activities of Knowledge Management			
		Creation	Storage	Sharing	Application
Level 1	–	–			
Level 2	Generic	Aware of the importance of Knowledge Management • defining Knowledge Management • discovering problems and potential values of Knowledge Management			
	Specific	Achievements of KM activities in specific scopes • encourage employees' creativity • knowledge documentation • informal knowledge sharing activities and application			
Typical enablers	Technology	Internet, Intranet, Extranet learning tools; GUI-aided designs; brainstorming software; virtual reality	bbs; text editors; data base	bbs; email; videoconference; groupware; chartrooms; communities of practice	interface design software
	Structure	Communities of practice			
Level 3	Generic	Organizational KM support • dedicated KM groups • invested resources			
	Specific	Formalized and integrated sub-processes of Knowledge Management • strategic and formalized mechanisms of knowledge creation • knowledge extraction and integration • formalized channels of knowledge sharing & training • contexts of knowledge applications			

(continued on next page)

Table D3 (*continued*)

Level	Objectives	Practiced activities of Knowledge Management			
		Creation	Storage	Sharing	Application
Typical enablers	Technology	Enterprise information portal, knowledge management system			
		Data mining; text retrieval/mining; knowledge discovering tools; instance inferencing system; simulation models; collaborative filters system; artificial intelligence; business intelligence	Knowledge base; data warehousing; documentation system; instance inferencing system; FAQ; workflow systems; expert systems	Search engine; knowledge taxonomy; knowledge map; intelligent agent; content-oriented search; e-learning; experts yellow page	Expert system; work scheduling; OLAP; DSS; intelligent agent
	Structure	Dedicated KM group, a dedicated project group, a flat organizational structure			
		R & D department;	Information management department	On job experts training; apprentice system; workshop	Functional department
Level 4		Quantitative control and assessment of knowledge management processes • stabilize the achievements of knowledge management sub-processes			
Enablers	Structure	Auditing department			
Level 5		Continually improving knowledge management processes • ensure improving knowledge management processes continually			
Enablers	structure	R & D group, decision making group			

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