E-ISNN: 2676-7007

FUZZY OPTIMIZATION AND MODELLING JOURNAL 5(1) (2024) 59-91

Contents lists available at FOMJ

Fuzzy Optimization and Modelling Journal

Journal homepage: https://sanad.iau.ir/journal/fomj/

Paper Type: Research Paper

Developing a Hybrid Fuzzy MCDM and MODM Model for Allocating Knowledge Management Tools and Practices to Organizational Knowledge Issues

Ehsan Yavari[a], Alireza Mardani[b], Mohammad Amin Mirarab Razi[c], Mohammad Reza Fathi[*, d]

[a] *Depratment of Industrial Management, Imam Hossein Comprehensive University, Tehran, Iran*
[b] *Department of Financial Management, Imam Hossein Comprehensive University, Tehran, Iran*
[c] *Department of Public Administration, Islamic Azad University, Sari Branch, Iran.*
[d] *Department of Management and Accounting, College of Farabi, University of Tehran, Qom, Iran*

ARTICLE INFO

Article history:
Received 14 January 2024
Revised 5 July 2024
Accepted 27 July 2024
Available online 30 July 2024

Keywords:
Knowledge Management Systems
Fuzzy Delphi
Best-Worst Method
Fuzzy TOPSIS
Allocation Model

ABSTRACT

Today, due to the lack of a systematic approach to selecting knowledge management (KM) tools and practices, various organizational units face different challenges, resulting in the organization's failure to achieve its goals. This study aims to propose a hybrid multi-attribute decision-making (MADM) and multi-objective decision-making (MODM) model to provide organizational managers with a systematic method for selecting KM tools and practices appropriate to the knowledge issues facing their organization. This study first identified the tools and practices in KM and then modified these tools and practices using the fuzzy Delphi method. After conducting a literature review, the criteria and sub-criteria used to evaluate these tools and practices were identified and weighted according to the Best Worst Method (BWM). A fuzzy TOPSIS method was then used to rank the tools and practices based on the weights derived from the criteria and sub-criteria. An allocation model using bi-objective mathematical programming was developed as a final step to allocate KM tools and practices to organizational knowledge issues. According to the analysis of the criteria and sub-criteria, "stakeholder satisfaction" ranks highest among the main criteria, while "capital costs," "knowledge transfer," and "customers" rank highest among the sub-criteria. Based on the evaluation of KM tools and practices, "social media" ranked first among tools, and "ideation sessions" ranked first among practices. Following the solution of the model, it was determined how each tool and practice should be allocated to knowledge issues. In general, 200 points were generated on the Pareto front as a result of solving the model.

[*] Correspondig author
E-mail address: Reza.fathi@ut.ac.ir (Mohammad Reza Fathi)

DOI:

1. Introduction

Enterprises are facing stiff global competition, and the best way to effectively lead competitors is to develop new products, new services, and new business models [40]. In recent years, academia and industry have given considerable attention to KM, to the point where many organizations are interested in applying it to gain a competitive advantage [19, 4]. Knowledge management systems (KMSs) are among the topics of interest in KM. KMSs consist of KM practices (techniques) and KM tools [8].

In addition to tools and practices, KM includes processes, strategies, and methodologies [39]. As a result of these tools and techniques, knowledge can be shared and processed within an organization. Furthermore, these tools and practices allow businesses to utilize knowledge in real-time and globally [42]. This is an issue that helps organizations survive in today's highly competitive market.

Nonetheless, it is essential to ensure that the organizational structures and the technologies used within the organization are integrated and harmonized [62, 59]. KMS is one of these technologies. Although managers are aware of the benefits of KM, they disagree about the methods for utilizing these knowledge sources, and there is a wide range of views and opinions in this area. Some managers believe that computers and modern technology are effective methods of utilizing knowledge. Those who believe that knowledge is stored in people's minds ignore the importance of technology [4]. Consequently, KM conditions and issues in a particular organization may differ from those in other organizations.

The effectiveness of a KM tool or technique for one organization is not a guarantee of its effectiveness for other organizations. Depending on the conditions and problems an organization faces, every organization uses its KM tools [56]. If there is an inconsistency between the organizational issues and KMSs, it will result in a lack of proper implementation of the KMS, which will adversely impact the company's operations [8, 60].

Alternatively, organizations may select the wrong KM tool or technique due to a misunderstanding of KM issues, resulting in significant costs for the organization. Thus, KM tools and practices require decision-makers to select appropriate alternatives while considering the conditions and consequences associated with each alternative [33]. Furthermore, the rapid advancement of technology and the high diversity of these technologies present a greater challenge to organizations when selecting KM tools and practices [42]. Based on Ngai and Chan [45], organizations should be capable of evaluating possible tools to select KM tools that are aligned with their organization's goals. Dawson [15] recommends that the KM solution chosen should be able to address the organization's problems as part of implementing a KM solution.

As stated by Büyüközkan and Feyzioglu [6], selecting an appropriate KM tool is essential to the success of the project at this stage of the implementation process.

In this study, we developed a four-phase methodology to address the mentioned issues and challenges. During the first phase, we utilized the Delphi method and conducted a literature review to identify tools and practices for KM. The evaluation criteria for these tools and practices were derived from the literature review. As a final step in the first phase, experts were interviewed, and open questionnaires were used to identify knowledge issues in organizations. During the second phase, criteria and sub-criteria were ranked using the Best-Worst Method (BWM). In the third phase, KM tools and practices were ranked using the fuzzy TOPSIS method. Finally, in the fourth phase, we developed a mathematical allocation programming model that can be used to solve organizational knowledge problems through appropriate KM tools and practices.

Since KM is an extremely important subject and continuously evolving, this research can serve as a foundation for future research. The remainder of the paper is organized as follows: Section 2 discusses the literature review. The research methodology is presented in Section 3, then applied to a case study in

Section 4, the results and discussion are presented in Section 5, and finally, conclusions and suggestions for future research are presented in Section 6.

2. Literature Review

Over the past few years, researchers have presented a variety of definitions of KMSs. Alavi and Leidner [3] defined KMSs as "IT-based systems that support KM development stages and include a set of information systems (e.g., data mining, learning tools, databases, forums, and expert systems)." Corso et al [13] defined KMSs as "organizational tools (e.g., project teams, databases for designing solutions, advanced communication tools, interactions with customers and suppliers) or technological tools (e.g., computer tools and product information management). KMSs are defined by Fink and Ploder [23] as "cost-effective methods and software products that facilitate the integration of knowledge across people, processes, technology, and organizational structures (e.g., brainstorming, knowledge networks, email systems, best practices, knowledge maps, storytelling, document management systems, and expert systems)." However, Centobelli et al [8] provided one of the most comprehensive definitions of KMSs. The definition also forms the basis for the current study, which asserts that KMSs combine KM practices (techniques) and tools. KM practices are a set of methods and techniques designed to support the development of KM processes within an organization. KM tools are IT-based systems that facilitate the implementation of KM practices. Nevertheless, the application and selection of KMSs in organizations have always been viewed as important issues, and several studies have been conducted in this regard. A comprehensive literature review has been conducted to identify these studies, briefly summarized in Table 1.

After reviewing the available articles on KMSs and utilizing the fuzzy Delphi method, fifteen tools and fifteen practices related to KM were identified, as shown in Table 2. In this table, A refers to tools and B refers to practices.

Following an extensive literature review, appropriate criteria and sub-criteria for evaluating KM tools and practices were identified, as shown in Table 3.

2.1. Efficacy

According to efficacy, the value of individuals within an organization increases when their knowledge is utilized through KMSs to enable them to accomplish their tasks effectively and efficiently. As a result, this criterion can be measured in terms of four basic elements of KM, i.e., knowledge creation, knowledge accumulation, knowledge transfer, and knowledge diffusion [31]. Knowledge creation is a key component of knowledge-based organizations, which involves acquiring and identifying knowledge from internal and external sources [46].

Knowledge creation occurs continuously within organizations and enables them to develop their capabilities, competencies, and interactions through their human resource (HR) skills [24]. Furthermore, it is important to preserve, organize, and make accessible the knowledge that has been created. In this context, knowledge accumulation is considered an important step since it allows employees to access a knowledge base that stores knowledge [28]. Knowledge transfer is the next critical issue. An organization's knowledge is distributed among its members through knowledge transfer. Since knowledge resides among organizational members, tools, and tasks and is often tacit and difficult to articulate, knowledge transfer is more complicated than mere communication. KM will fail if the potential of the knowledge created cannot be fully utilized. Finally, the last sub-criterion is knowledge diffusion, which contributes to knowledge sharing and innovation within the organization [24].

Table 1. Previous studies on the selection of knowledge management systems (KMSs)

Authors/Year	Purpose	Methodology	Findings
Wei et al [63]	Assessing Knowledge Quality Using Fuzzy MCDM Model	Analytic hierarchy process (AHP)	The results show that the method finally judges six knowledge instances as qualified and three as unqualified. The results show that the proposed method can indeed assist enterprises to effectively screen knowledge proposals.
Dorfeshan et al [16]	A New Data-driven and Knowledge-driven Multi-criteria Decision-making Method	ELECTRE and VIKOR	All proposed methods for weighting and rankings are developed under grey numbers for coping with the uncertainty. Finally, the practicality and applicability of the proposed method are proved by solving an illustrative example.
Kaya et al [34]	A novel integration of MCDM methods and Bayesian networks: the case of incomplete expert knowledge	DEMATEL and TOPSIS	A scenario analysis with 5% to 20% of missing values with an increment of 5% is conducted to demonstrate that our approach remains robust as the level of missing values increases.
Ronaghi et al [53]	Identification and Ranking the Factors Affecting the Knowledge Management Implementation Using Metasynthesis Method	Meta-Synthesis	A successful KM program will consider more than just technology. An organization should also consider organization culture, leadership, strategic alignment, managers' support, information technology and motivation were identified as the most important factors for success of KM implementation.
Eslamkhah & Hosseini [18]	Presenting an approach to evaluating and ranking the role of KM tools and techniques	Fuzzy Screening, DEMATE, ANP & VIKOR	This study identified 62 KM-related tools and techniques, which were then reduced to 20 tools and techniques. Based on the research findings, "knowledge base" was identified as the most critical factor in the creation and recording of knowledge. In addition, the "classification of knowledge" technique received the highest score in the area of sharing and diffusing knowledge. Among the tools used to apply knowledge, the "Knowledge Map" tool achieved the highest score.
Agrawal [2]	The development of a systematic approach to discovering cause-and-effect relationships between KM processes	ISM & DEMATEL	According to the results, knowledge creation and knowledge absorption are the most important KM processes among the eight identified KM processes. In contrast, knowledge organization and knowledge application are highly interconnected processes.

Table 2. KM tools and practices approved by experts

Practices (B)		Tools (A)	
Knowledge discovery interview (B8)	Knowledge Café (B1)	Podcasts and videocasts (A8)	Blogs (A1)
Brainstorming (B9)	Expert forum (B2)	Document management system (A9)	Advanced search tools (A2)
Storytelling (B10)	Classification (B3)	Audio and video conferencing (A10)	KM evaluation tools (A3)
Ideation sessions (B11)	Coaching (B4)	Crowdsourcing system (A11)	Social Media (A4)
Seminar (B12)	After action review (B5)	Data mining (A12)	Expert systems (A5)
Job rotation (B13)	Knowledge mapping (B6)	Data management systems (A13)	Content management systems (A6)
Learning Review (B14)	Knowledge modeling (B7)	Decision Support System (A14)	Wikis (A7)
Collaborative Assistance (B15)		Cloud Computing (A15)	

Table 3. Criteria and sub-criteria for evaluating KM tools and practices

References	Sub-criteria	Criteria
Efficacy (E)	Knowledge creation (E1)	[34,61,31,28,24,25,38,63,50,21,22,1]
	Knowledge accumulation(E2)	
	Knowledge transfer (E3)	
	Knowledge diffusion (E4)	
Application (A)	Personalization (A1)	[63,5,55,47,24,7]
	Collaboration and communication (A2)	
	Integration (A3)	
	Tracking and monitoring (A4)	
Cost (C)	Capital cost (C1)	[32,41,24,45,14,57,7,30,43,49,44,20]
	Operating cost (C2)	
	Development costs (C3)	
Stakeholder satisfaction (S)	Customers (S1)	[47,24,7,34]
	Staff (S2)	
	Shareholders (S3)	
	Suppliers (S4)	

2.2. Application

The application feature focuses on the technical and hardware aspects of KM tools and practices. Personalization, collaboration and communication, integration, and tracking and monitoring are characteristics used to measure this criterion. Users can customize their profiles and gain access to KMSs through internal networks (intranets) and the Internet. It facilitates the exchange and development of knowledge between managers and employees [5,55]. Furthermore, collaboration in problem-solving, knowledge sharing, discussion, and teamwork contribute significantly to an organization's knowledge assets.

Collaboration and communication enable KMSs to exchange knowledge and create knowledge [55]. KMS allows an organization to expose and share information continuously within and among its users [47]. Lastly, tracking and monitoring refer to controlling and monitoring user behavior in knowledge sharing through automated information and communication processes [47].

2.3. Cost

Managers must also consider the cost factor when selecting a KMS. Funds available for purchasing KMSs cover maintenance, long-term operating, and user training costs [14]. Since this criterion includes expenditures related to product licensing, training, maintenance, and software subscriptions and development, it can also be classified into capital, operating, and development costs. Operating costs refer to expenses continuously incurred in the organization, such as maintenance and training costs and subscription fees for KMSs that organizations must pay throughout their usage.

Capital costs are non-recurring expenses based on two factors: hardware and software [24]. The KMSs do not typically include a single application, so they can be used for primary and other tasks. Thus, development costs include the costs associated with the systematic expansion and generalization of KMSs within an organization so that they may be used across departments and tasks [30].

2.4. Stakeholder satisfaction

Furthermore, stakeholders' and employees' satisfaction in terms of positive impact on customer relationships, HR development, and shareholder profitability is another important factor to consider. A key component of management decisions should be stakeholder satisfaction. Four sub-criteria can be assigned to this criterion: customers, employees, shareholders, and suppliers. It is necessary for any organization to address the needs of its customers and to establish a good relationship with them in a competitive market. An organization's primary focus should be on its customers. Customer relationship management (CRM) can play a significant role in acquiring organizational knowledge and using it to gain a competitive advantage when combined with appropriate technology. An organization's human resource management (HRM) is also a significant factor in its success.

KM emphasizes employees' importance in creating, sharing, and acquiring knowledge within an organization. Thus, KMSs should assist companies in creating, sharing, and codifying existing knowledge [24]. Moreover, utilizing existing knowledge within an organization positively impacts cost reduction, time management, HR development, new product development, and knowledge sharing. As a result, shareholder perspectives have become increasingly significant in this context [47]. Additionally, when choosing a KMS, it is imperative to consider reputation, service, and support.

Having identified the tools and practices and the appropriate criteria for evaluating them, we distributed open questionnaires to the research experts to ask them to identify knowledge problems that are primarily present within the organization. Table 4 presents a list of ten common problems organizations face in the field of KM.

3. Methodology

Figure (1) illustrates a four-phase methodology for allocating KM tools and practices to large organizations. The first phase of the research involved a thorough literature review and interviews with KM managers and experts to identify twenty tools and twenty practices in KM. Using the fuzzy Delphi method, five tools and five practices were eliminated. In total, fifteen tools and fifteen practices were finalized. The literature review also yielded four main criteria and fifteen sub-criteria for evaluating these tools and practices. These criteria and sub-criteria were also approved after several discussions with managers and organizational experts. At the end of the first phase of the research, ten main KM-related problems that organizations are facing were identified through interviews with experienced managers and organizational experts. A second phase of the research involved ranking criteria and sub-criteria for evaluating KM tools and practices. We ranked criteria and sub-criteria using BWM proposed by Rezaei [51,52]. Because BWM performs fewer pairwise comparisons than other techniques such as AHP, it has an advantage over other MCDM techniques. Additionally, since all alternatives are compared with both the best and worst alternatives, BWM is relatively less data-intensive [51].

Table 4. Organizational knowledge problems

KM-related problems	Description
File and information search and retrieval (P1)	With a large amount of data and information generated within organizations, searching and retrieving information is a critical issue.
Knowledge creation (P2)	Organizations also face the issue of discovering and creating completely new knowledge.
Knowledge accumulation (P3)	Organizations often lack the necessary technology to accumulate knowledge, making it difficult to retrieve and utilize that knowledge in the future.
Knowledge transfer (P4)	There are times when organizational structures are designed to prevent knowledge transfer.
Knowledge valuation (P5)	The issue of knowledge valuation arises when organizations have difficulty recognizing the quality of knowledge available within their organization and the type of knowledge they need.
Collaboration and knowledge sharing (P6)	Organizational units are generally reluctant to collaborate and share their knowledge.
Decision-making (P7)	Since organizations usually make decisions based on past knowledge and information, KM plays an instrumental role in the decision-making process.
The conversion of tacit knowledge into explicit knowledge (P8)	As people leave an organization, their knowledge is lost since some organizations lack the knowledge and technology to absorb knowledge into people's brains.
Organizational knowledge security (P9)	Some organizations may not have the appropriate platforms or structures to protect their organizational knowledge, resulting in the loss or transfer of such information outside of the organization.
Knowledge benchmarking (P10)	Knowledge benchmarking involves identifying areas of the organization where knowledge exists, and sometimes organizations cannot identify these areas.

The fuzzy TOPSIS method was used in the third phase to rank KM tools and practices. A wide range of studies has been conducted using fuzzy TOPSIS [58,12,36,11]. Finally, the fourth phase involved the development of a bi-objective linear programming model for allocating tools and/or practices to KM issues according to cost reduction and accessibility objectives. Based on the results of the BWM and fuzzy TOPSIS questionnaires, the proposed model was solved using GAMS optimization software version 24.3 and the ε-constraint method.

3.1 Calculate the Weight of Criteria and Sub-Criteria for Evaluating KM Tools and Practices using BWM

We used BWM to determine the weight of the criteria and sub-criteria used in evaluating KM tools and practices. As described by Rezaei [51,52], BWM involves the following steps:

Step 1: This step involves defining a set of decision criteria as $\{c_1, c_2, \dots, c_n\}$, which is needed to make a decision. The study includes four main criteria: efficacy, application, cost, and stakeholder satisfaction. Each criterion consists of several sub-criteria.

Step 2: Identify the best (most important, most desirable) and the worst (least important, least desirable) criteria. During this step, the decision maker determines the best and worst criteria. This step does not involve any comparisons.

Step 3: Using the numbers 1 to 9, determine the preference for the best criterion over all other criteria. The Best-to-Others preference vector is represented as $A_B = (a_{B1}, a_{B2}, \dots, a_{Bn})$, where a_{Bj} represents the preference for the best criterion (B) over the criterion (j). It is evident that $a_B = 1$.

Step 4: Utilize the numbers 1 to 9 to determine the preference of all criteria over the worst criterion. The Others-to-Worst preference vector is represented as $A_W = \left(a_{\backslash W}, a_{2w}, \dots, a_{nW}\right)^T$, where a_{jW} denotes the preference of criterion (j) over the worst criterion (W). As a result, $a_W = 1$. Table 5 presents the linguistic scales used in comparing the BWM.

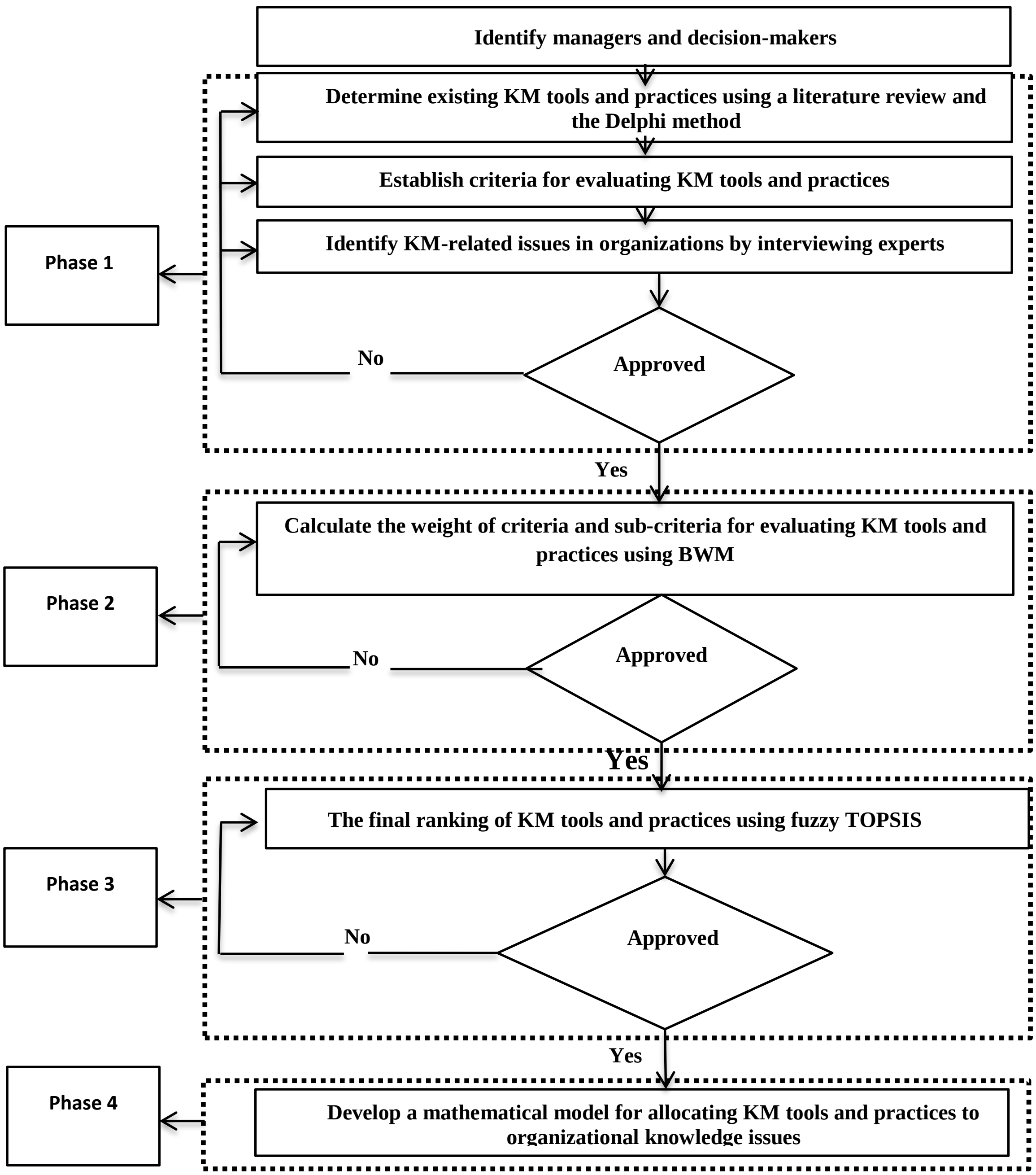

Figure 1. A schematic representation of the research process

Table 5. A linguistic scale for comparing BWM [51]

Equal importance	Very weak importance	Weak importance	Preferably importance	Good importance	Relatively good importance	Very good importance	Absolute importance	Perfect importance
1	2	3	4	5	6	7	8	9

Step 5: Determine the optimal values for the weights $(w_1^*, w_2^*, \dots, w_n^*)$. To determine the optimal weight of each criterion, the pairs $\frac{w_B}{w_j} = a_{Bj}$ and $\frac{w_j}{w_w} = a_{jw}$. It must be possible to find a solution that ensures that the terms $\left|\frac{w_B}{w_j} - a_{Bj}\right|$ and $\left|\frac{w_j}{w_w} - a_{jw}\right|$ are valid for all j that is minimized. Based on the non-negativity of the weights and the sum condition of the weights, the model can be formulated as follows:

$$\min \max \left\{ \left|\frac{w_B}{w_j} - a_{Bj}\right|, \left|\frac{w_j}{w_w} - a_{jw}\right| \right\}$$
s.t.
$$\sum_j w_j = 1$$
$$w_j \geq 0, \text{ for all } j \qquad (1)$$

Model (1) can also be converted into Model (2) as follows:
$$\sum_j w_j = 1$$
$$w_j \geq 0, \text{ for all } j \qquad (2)$$

Following is a linear model of the above function. Our study utilizes a linear model (3) to determine the criteria weights.

$$\min \xi$$
s.t.
$$\left|w_B - a_{Bj} w_j\right| \leq \xi, \text{ for all } j$$
$$\left|w_j - a_{jw} w_w\right| \leq \xi, \text{ for all } j$$
$$\sum_j w_j = 1$$
$$w_j \geq 0, \text{ for all } j \qquad (3)$$
As a result of solving model (3), we determine the optimal values for $(w_1^*, w_2^*, \dots, w_n^*)$ and ξ^*.

3.1.1 Consistency Rate for BWM

Based on the obtained ξ^*, the consistency rate is calculated. There is no doubt that a higher ξ^* indicates a higher consistency rate. Since $a_{Bj} \times a_{jw} = a_{BW}$ and $a_{BW} \in \{1, 2, \dots, 9\}$, the consistency rate can be determined using the consistency indices in Table 6 and Eq. (4).

Table 6. Consistency indices

a_{BW}	1	2	3	4	5	6	7	8	9
Consistency index	5.23	4.47	3.73	3.00	2.30	1.63	1.00	0.44	0.00

$$\text{Consistency rate} = \frac{\xi^*}{\text{Consistency index}} \qquad (4)$$

A consistency rate closer to zero indicates that comparisons will be more consistent. As the BWM technique makes it easy to collect data and calculate weights, it was used to determine the criteria weights (Rezaei, 2015).

3.2 The Final Ranking of KM Tools and Practices using Fuzzy TOPSIS

The TOPSIS method is based on the assumption that there are *n* criteria and *m* alternatives. There is a minimum distance between the selected alternative and the positive ideal solution and a maximum distance between the selected alternative and the negative ideal solution. TOPSIS requires managers to rate alternatives according to their preferences, making it difficult for managers to assign accurate ratings. The fuzzy TOPSIS method is proposed to overcome this limitation, in which managers evaluate ratings using fuzzy numbers [9,58].

Following are the steps involved in fuzzy TOPSIS:

Step 1: As shown in Table 7, the scales are used to create the decision matrix, which involves comparing alternatives (KM tools and practices) based on the criteria studied. This study uses linguistic expressions and triangular fuzzy numbers.

Table 7. Linguistic expressions to compare alternatives [54]

Fuzzy number	Linguistic expression	Triangular fuzzy scale
$\tilde{9}$	Perfect importance	(8,9,10)
$\tilde{8}$	Absolute importance	(7,8,9)
$\tilde{7}$	Very good importance	(6,7,8)
$\tilde{6}$	Relatively good importance	(5,6,7)
$\tilde{5}$	Good importance	(4,5,6)
$\tilde{4}$	Preferably importance	(3,4,5)
$\tilde{3}$	Weak importance	(2,3,4)
$\tilde{2}$	Very weak importance	(1,2,3)
$\tilde{1}$	Equal importance	(1,1,1)

Step 2: Create a fuzzy decision matrix, which contains *m* alternatives $(A_1, A_2, A_3, \ldots, A_m)$, and *n* criteria $(C_1, C_2, C_3, \ldots, C_n)$ by considering *k* decision makers $(D_1, D_2, D_3, \ldots, D_K)$.

where r_{mn} represents the rank of alternative A_m according to criterion c_n. In this study, A_m includes tools and practices associated with KM. Furthermore, c_n includes the criteria identified for evaluating tools and practices based on literature reviews and expert approval.

Step 3: Aggregated fuzzy ranking for the alternatives:

The N^{th} fuzzy ranking of a decision maker is $\tilde{x}_{abN} = (I_{abN}, P_{abN}, U_{abN})$ where $a = 1,2,3,4,5, \ldots, m$ and $b = 1,2,3,4,5, \ldots, n$. Then the aggregated fuzzy ranking $\tilde{x}_{ab}$ for alternatives are given according to each criterion as $\tilde{x}_{ab} = (I_{ab}, P_{ab}, U_{ab})$ where:

$$a = min(I_{abN}) \quad (5)$$

$$b = \frac{1}{N}\sum_{n=1}^{N}(P_{abN}) \quad (6)$$

$$C = max(U_{abN}) \quad (7)$$

Step 4: Construct a normalized fuzzy decision matrix

The normalized fuzzy decision matrix represented by $\tilde{B}$ is defined as follows:

$$\tilde{B} = [p_{ij}]_{m\times n} \quad (8)$$

where $i = 1,2,3,4,5, \dots, m$ and $j = 1,2,3,4,5, \dots, n$.

$$\tilde{p} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) \text{and } c_j^* = \max c_{ij} \text{ (Profit Criterion)} \quad (9)$$

$$\tilde{p} = \left(\frac{a_j^-}{a_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{c_{ij}}\right) \text{and } a_j^- = \min a_{ij} \text{ (Cost Criterion)} \quad (10)$$

This study considers efficacy, application, and stakeholder satisfaction as profit criteria since we seek to maximize them. A cost-related criterion is relevant since we strive to minimize expenditures.

Step 5: The weighted fuzzy normalized decision matrix is represented as:

$$\tilde{V} = [\tilde{v}_{ij}]_{m\times n} \quad i = 1,2,3, \dots, m \text{ and } j = 1,2,3, \dots, n$$

$$\tilde{V} = \tilde{P}_{ij} \times w_j \quad (11)$$

Step 6: Determine fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS)

$$A^+ = \{v_1^+, \dots, v_n^+\}, \text{where } v_j^+ = \{\max(v_{ij}) \text{if } j \in J; \min(v_{ij}) \text{if } j \in \acute{J}\}, j = 1,2,3,4,5, \dots, n \quad (12)$$

$$A^- = \{v_1^-, \dots, v_n^-\}, \text{where } v_j^- = \{\min(v_{ij}) \text{if } j \in J; \max(v_{ij}) \text{if } j \in \acute{J}\}, j = 1,2,3,4,5, \dots, n \quad (13)$$

FPIS includes the maximum value of the fuzzy upper bound of the normalized weighted matrix for the three criteria of efficacy, application, and stakeholder satisfaction, whereas FNIS includes zero values.

Based on the cost criterion, FPIS contains the maximum value of the fuzzy lower bound of the normalized weighted matrix, and FNIS contains the minimum value of zero.

Step 7: Calculate the distance of each alternative from FPIS and FNIS

$$d_j^+ = \{\sum_{j=1}^{n}(v_{ij} - v_{ij}^+)^2\}^{\frac{1}{2}}, i = 1, \dots, m \quad (14)$$

$$d_j^- = \{\sum_{j=1}^{n}(v_{ij} - v_{ij}^-)^2\}^{\frac{1}{2}}, i = 1, \dots, m \quad (15)$$

The equations above are used to calculate the distance between each KM tool and practice from FPIS and FNIS. Once the distances between each tool and practice have been aggregated based on their criteria, the distance between each alternative and FPIS and FNIS will be determined.

Step 8: Calculate the closeness coefficient (CC_i) for each alternative using Eq. (16):

$$CC_i = \frac{d_i^-}{d_i^- + d_i^+}, i = 1, \dots, m. \quad c_i \in (0,1) \quad (16)$$

In this step, we calculate CC_i for each KM tool and practice based on the above equation.

Step 9: Ranking the alternatives

In this step, KM tools and practices are ranked in descending order based on CC_i.

3.3 A Mathematical Programming Model for Allocation

It is assumed that when KM is applied to an organization, there will be various problems and several tools and/or practices to address these challenges. In general, all these tools and/or practices incur costs for the organization. Since the budget is limited, only some of them can be implemented. However, the appropriateness of each tool and/or practice to address the issues in KM varies.

Accordingly, the main objectives of the problem were to reduce cost and increase accessibility. The study aims to develop a model for allocating KM tools and/or practices to organizational knowledge issues to achieve the intended goals. It is necessary to consider assumptions to model the allocation problem, like other mathematical models. This research is based on the following assumptions:

- There are a limited number of KM tools available.
- The number of KM practices (techniques) is limited.
- KM involves a limited number of issues.
- Each tool and/or practice has varying levels of accessibility.
- Various tools and/or practices can be implemented at different costs.

Sets

i	Set of tools	$i = \{1,2,\ldots,m\}$
j	Set of techniques (practices)	$j = \{1,2,\ldots,n\}$
k	Set of knowledge issues	$k = \{1,2,\ldots,p\}$

Parameters

C_{ik}	Cost of implementing the tool i for the problem k
C''_{jk}	Cost of implementing technique (practice) j for problem k
A_{ik}	The accessibility level of tool i for the problem k
A''_{jk}	Accessibility level of technique (practice) j for problem k
W_i	The total weight (preference degree) of tool i
W''_j	The total weight (preference degree) of technique (practice) j
BD	The amount of available budget
TN	Threshold limit for the efficacy of tools
TM	Threshold limit for the efficacy of practices
TP_k	The maximum number of tools allowed to be allocated to each problem
TQ_k	The maximum number of practices allowed to be allocated to each problem
M	A very large number

Decision variables

d_i	is 1 if tool i is considered to be an effective KM tool; otherwise, it is 0.
q_j	is 1 if technique (practice) j is considered to be an effective KM practice; otherwise, it is 0.
x_{ik}	is 1 if tool i is allocated to problem k; otherwise, it is 0.
y_{jk}	is 1 if practice j is allocated to problem k; otherwise, it is 0.

Mathematical Model

$$\text{Min}Z_1 = \sum_{i=1}^{m}\sum_{k=1}^{p} C_{ik}x_{ik} + \sum_{j=1}^{n}\sum_{k=1}^{p} C''_{jk}y_{jk} \quad (17)$$

$$\text{Max}Z_2 = \sum_{i=1}^{m}\sum_{k=1}^{p} A_{ik}x_{ik} + \sum_{j=1}^{n}\sum_{k=1}^{p} A''_{jk}y_{jk} \quad (18)$$

s.t

$$\sum_{i=1}^{m}\sum_{k=1}^{p} C_{ik}x_{ik} + \sum_{j=1}^{n}\sum_{k=1}^{p} C''_{jk}y_{jk} \leq BD \quad (19)$$

$$\sum_{i=1}^{m} w_i d_i \geq TN \tag{20}$$

$$\sum_{j=1}^{n} w_j^{"} q_j \geq TM \tag{21}$$

$$\sum_{k=1}^{p} x_{ik} \leq Md_i \qquad \forall\, i \tag{22}$$

$$\sum_{k=1}^{p} y_{jk} \leq Mq_j \qquad \forall\, j \tag{23}$$

$$\sum_{i=1}^{m} x_{ik} \leq TP_k \qquad \forall\, k \tag{24}$$

$$\sum_{j=1}^{n} y_{jk} \leq TQ_k \qquad \forall\, k \tag{25}$$

$$\sum_{i=1}^{m} x_{ik} + \sum_{j=1}^{n} y_{jk} \geq 1 \qquad \forall\, k \tag{26}$$

$$x_{ik}, y_{jk}, d_i, q_j \in \{0,1\} \qquad \forall\, i, j, k \tag{27}$$

The proposed model includes two objective functions, which are described below. The first objective function (17) refers to cost minimization, which is composed of two components. Costs associated with implementing KM-related tools constitute the first component. In addition, the second component relates to the costs of implementing practices to solve KM problems. The second objective function (18) aims to maximize the accessibility level of tools and/or practices to address organizational knowledge issues. Eight constraints are also included in the model. The budget constraint is considered in Expression (19). The efficacy of the tools should not fall below the threshold, according to Expression (20). Expression (21) guarantees that the efficacy of practices should not fall below the threshold. According to Constraint (22), a tool must be allocated to knowledge issues if it is selected as an effective KM tool. If a practice is selected as an effective KM practice, it must be allocated to knowledge issues, according to Constraint (23). Constraint (24) ensures that the number of tools assigned to each problem does not exceed the threshold. Constraint (25) guarantees that the number of practices assigned to each problem does not exceed the threshold. Each problem is assigned at least one tool and/or method as a result of Constraint (26). Finally, Constraint (27) determines the type of variables to be used in the problem.

3.3.1. ε-Constraint Method

Generally, a bi-objective minimization problem can be expressed as follows:

$$min\, f(X) = (f_1(X), f_2(X)) \tag{28}$$
$$s.t$$
$$X \in D \tag{29}$$

where $X = (x_1, x_2, \dots, x_n)$ indicates the vector of decision variables, and D denotes the solvable space of the problem. Comparing two different solutions to a multi-objective problem is much more challenging than comparing two solutions to a single-objective problem. There is often no single optimal solution to multi-objective problems, and a set of Pareto optimal solutions is presented as an efficient solution. In a minimization problem with m objective functions, the solution $u \in D$ over the solution $v \in D$ is said to be Pareto dominant if and only if the solution u is equal or superior to the solution v for all objective functions, and strictly superior to the solution v for at least one objective function. A solution u is considered a Pareto optimal solution if and only if it is not dominated by the solution v. Therefore, a Pareto optimal solution is one in which at least one objective function is improved to obtain a suboptimal value for that objective function. Pareto optimal solutions are referred to as efficient solutions. The efficient set includes all efficient solutions to a problem.

There are two Pareto fronts in the present study. On the first front, we seek to minimize the costs associated with applying tools and practices to organizational knowledge issues. Furthermore, we aim to make these tools and practices as accessible as possible for organizational knowledge issues. According to experts, maximum accessibility is more critical than cost minimization in this study. Therefore, on the Pareto front that we have, we will strive to find a point that will provide us with maximum accessibility to tools and practices at the lowest possible cost. When we reach this point on the research Pareto front, we will be able to determine the allocation of each tool and practice to each knowledge issue.

The ε-constraint method is one of the most well-known methods for solving multi-objective optimization problems. As a result of this method, an objective is optimized rather than incorporating objective functions into a function, and other objective functions are transformed into constraints known as ε-constraints [17]. The method was initially developed by Haimes et al [29] and Chankong and Haimes [10] provide a detailed description. The ε-constraint is one of the most well-known approaches to solving multi-objective problems, which involves transferring all objective functions except one into a constraint at each step. Pareto fronts can be created using the ε-constraint method.

$$min\, f(X) = f_1(X) \tag{30}$$
$$s.t$$
$$X \in D \tag{31}$$
$$f_1(X) \le \varepsilon_2$$
$$\dots$$
$$f_n(X) \le \varepsilon_n \tag{32}$$

The ε-constrain method involves the following steps:

1) Select one of the objective functions as the primary objective function.
2) Each time, solve the problem according to one of the objective functions and determine the optimal value for each objective function.
3) Divide the interval between two optimal values of the secondary objective functions by a predetermined number and calculate a table of values for $\varepsilon_2, \dots, \varepsilon_n$.
4) Solve the problem each time using the primary objective function based on $\varepsilon_2, \dots, \varepsilon_n$.
5) Prepare a report on the Pareto solutions.

4. An Application of the Proposed Methodology to a Case Study

This section presents a case study illustrating the four-phase methodology described in Section 3. It is helpful to examine the robustness of the proposed model for analysis by presenting a real-world case study. Thus, in this study, four organizations involved in KM projects were used as case studies, and two experts from each organization were selected as participants.

4.1 Calculate the Weight of Criteria and Sub-Criteria using BWM

After finalizing the criteria and sub-criteria for evaluating KM tools and practices by managers, the next step was to determine how these criteria and sub-criteria should be weighted. Therefore, managers were asked to rate the main criteria and sub-criteria. Eight experts compiled a comprehensive list of the best and worst main criteria and sub-criteria, which is presented in Table 8. According to BWM, the best criterion is the one that is the most important criterion in the study, and the worst criterion is the one that has the least importance.

Table 8. Experts' evaluations of the best and worst criteria and sub-criteria

Criteria and sub-criteria for evaluating KM tools and practices	Determined as "the best" by experts	Determined as "the worst" by experts
Efficacy (E)	1,2	6,7
E1	-	1,4,5,7,8
E2	3	6
E3	2,4,5,7,8	-
E4	1,6	2,3
Application (A)	7,8	1,2,3,5
A1	1,3	2,5
A2	5,8	6
A3	2,4,6,7	-
A4	-	1,3,4,7,8
Cost (C)	4,6	8
C1	2,4,5,7,8	-
C2	1,3,6	4,7,8
C3	-	1,2,3,5,6
Stakeholder satisfaction (S)	3,5	4
S1	2,4,5	-
S2	1,3,6	4,7,8
S3	-	1,6
S4	7,8	2,3,5

First, the weights of the main criteria are calculated according to the methodology described in Section 3. As shown in Table 9, Expert 1 rated the main criteria.

Table 9. Pairwise comparison of the main criteria by Expert 1

S	C	A	E	S
Best criterion (E)	1	2	4	8
	Worst criterion (A)	-	-	-
E	8	-	-	-
A	1	-	-	-
C	3	-	-	-
S	5	-	-	-

Alternatively, managers were asked to score the sub-criteria according to the methodology described in Section 3. Tables 10 to 13 show the scores for the sub-criteria by Expert 1.

Table 10. Pairwise comparison of the "efficacy" criterion by Expert 1

S	C	A	E	S
Best criterion (E4)	8	1	4	2
	Worst criterion (E1)	-	-	-
E1	1	-	-	-
E2	3	-	-	-
E3	2	-	-	-
E4	8	-	-	-

Table 11. Pairwise comparison of the "application" criterion by Expert 1

	A1	A2	A3	A4
Best criterion (A1)	1	5	2	7
	Worst criterion (A4)	-	-	-
A1	7	-	-	-
A2	2	-	-	-
A3	3	-	-	-
A4	1	-	-	-

Table 12. Pairwise comparison of the "cost" criterion by Expert 1

	S1	S2	S3	S4
Best criterion (S2)	2	1	7	3
	Worst criterion (S3)	-	-	-
S1	5	-	-	-
S2	7	-	-	-
S3	1	-	-	-
S4	2	-	-	-

Table 13. Pairwise comparison of the "stakeholder satisfaction" criterion by Expert 1

	C1	C2	C3
Best criterion (C2)	2	1	7
	Worst criterion (C3)	-	-
C1	5	-	-
C2	7	-	-
C3	1	-	-

Next, we determine the weight of the main criteria and sub-criteria based on the pairwise comparison of the main criteria and sub-criteria by experts. We calculated the weight of the main criteria and sub-criteria using Eq. (3). The average weights resulting from the scores of eight experts are presented in Table 14. Weights for the main criteria and sub-criteria were first calculated individually based on each expert's viewpoint, and then these viewpoints were aggregated according to their average weights. In addition, the aggregated consistency rate was calculated using a similar method.

It is evident from Table 14 that "stakeholder satisfaction" is the most important of the main criteria. In addition, "capital cost", "knowledge transfer", and "customers" have gained the most weight among the sub-criteria.

4.2 The Ranking of KM Tools and Practices using Fuzzy TOPSIS

The next step is to determine the ranking of KM tools and practices based on the weight of the main criteria and sub-criteria. KM tools and practices were ranked using fuzzy TOPSIS, which was discussed in the third part of the methodology. As shown in Table 7, eight organizational experts were asked to rate these tools and practices based on linguistic scales. Table 15 and Table 16 provide the results of the decision matrix for KM tools and practices.

Table 14. Aggregated weights of the main criteria and sub-criteria for each expert

Main criteria	Rank	Final weight	Aggregated consistency rate of sub-criteria	Local weight	I.D. code	Sub-criterion	Aggregated consistency rate of the main criteria	Local weight
Main criteria Efficacy (E)	14	0.0337	0.055	0.130	E_1	Knowledge creation	0.058	0.259
	9	0.0580		0.224	E_2	Knowledge accumulation		
	2	0.1010		0.390	E_3	Knowledge transfer		
	7	0.0666		0.257	E_4	Knowledge diffusion		
Application (A)	10	0.0545	0.061	0.261	A_1	Personalization		0.209
	11	0.0541		0.259	A_2	Collaboration and communication		
	5	0.0709		0.339	A_3	Integration		
	15	0.0295		0.141	A_4	Tracking and monitoring		
Cost (C)	1	0.1401	0.030	0.543	C_1	Capital cost		0.258
	4	0.0818		0.317	C_2	Operating cost		
	13	0.0361		0.140	C_3	Development cost		
Stakeholder satisfaction (S)	3	0.0950	0.036	0.348	S_1	Customers		0.273
	6	0.0693		0.254	S_2	Staff		
	12	0.0467		0.171	S_3	Shareholders		
	8	0.0620		0.227	S_4	Suppliers		

Table 15. Pairwise comparison matrix of KM tools

A15	A14	A13	...	A3	A2	A1	
2.1	1.9	2.9	...	1.7	2.0	3.5	E_1
4.7	6.4	6.3	...	4.3	5.0	4.6	
6.6	8	8.2	...	6.7	7.2	7.8	
3.3	3.3	1.8	...	3.1	1.9	3.3	E_2
4.7	6.1	5.3	...	4.6	6.4	5.3	
8	8.5	7.2	...	7.2	8.3	8.1	
2.3	2.1	2.6	...	2.9	3.2	3.4	E_3
6.0	5.6	4.8	...	6.4	4.3	5.5	
8.7	7.4	7.1	...	8	7	6.9	
1.5	3.3	1.5	...	3.4	1.7	2.4	E_4
4.1	6.4	6.5	...	6.0	5.0	5.4	
8.2	7.4	8.6	...	6.9	7.3	6.6	
...	...	...	...	...	...	...	...
1.9	3.4	1.6	...	1.8	1.5	2.6	S_1
4.0	4.8	5.9	...	4.7	6.3	4.4	
7.9	7.6	7.8	...	7.1	7.5	6.8	
1.7	1.9	1.6	...	2.1	1.7	1.8	S_2
6.2	4.6	6.2	...	5.7	4.9	4.4	
7	7.2	7.3	...	8.5	7.4	8.4	
3.0	1.8	3.5	...	2.3	2.8	2.4	S_3
6.1	6.5	4.2	...	6.0	6.1	5.9	
7.3	8.3	6.6	...	8.5	7.6	8.2	
2.7	1.7	3.5	...	2.7	1.5	2.2	S_4
5.8	5.0	6.4	...	5.7	5.3	6.1	
8	8.1	6.6	...	7.5	8.3	8.7	

Table 16. Pairwise comparison matrix of KM practices

B15	B14	B13	...	B3	B2	B1	
1.9	2.9	2.2	...	2.9	3.5	3.0	E_1
5.2	6.5	4.9	...	5.8	6.5	5.3	
8	7.9	7.6	...	7.2	7.6	8.2	
3.5	3.0	3.3	...	1.5	3.2	2.6	E_2
5.1	4.9	4.3	...	4.3	4.3	4.1	
7.9	8.7	8.1	...	7.7	8.5	7	
2.2	2.9	3.0	...	1.6	2.1	2.4	E_3
5.3	6.1	4.5	...	5.4	4.0	4.7	
8.1	6.8	8.5	...	7.1	8.2	6.9	
1.9	1.9	1.9	...	3.0	3.2	1.6	E_4
5.9	5.2	4.0	...	4.4	4.1	4.7	
7	7.7	8.6	...	8.3	7.6	7.1	
...	...	...	...	...	...	...	...
1.7	2.1	1.9	...	3.1	1.7	2.6	S_1
4.5	5.8	4.0	...	5.5	5.8	5.6	
6.8	6.7	8.2	...	8.5	7.3	8	
2.4	3.5	2.7	...	1.8	1.5	2.5	S_2
5.0	5.5	6.5	...	4.4	5.3	4.7	
6.6	7.4	7.3	...	8	7.9	8.4	
1.7	1.9	1.9	...	2.4	1.6	2.0	S_3
5.2	4.3	6.4	...	4.9	5.3	6.3	
8.7	8.2	6.7	...	7.1	8.5	6.7	
1.7	2.5	3.0	...	2.1	2.4	1.7	S_4
5.0	5.3	5.1	...	6.3	4.3	6.0	
7.3	8	8.1	...	7.9	7.3	7.5	

As a result, we determined the normalized fuzzy matrices using Eq. (11), as shown in Tables 17 and 18. Eqs. (12) and (13) were also utilized to calculate the FPIS, ‹A^+, and FNIS, A^-. This study determined FPIS and FNIS on $\tilde{V}_1^+ = (1,1,1)$ and $\tilde{V}_1^- = (0,0,0)$, respectively. Regarding profit criteria, $\tilde{V}_1^+ = (1,1,1)$ and $\tilde{V}_1^- = (0,0,0)$ were determined. Based on cost criteria, $\tilde{V}_1^+ = (0,0,0)$ and $\tilde{V}_1^- = (1,1,1)$ were calculated.

Following the calculation of the weighted fuzzy matrix, the closeness coefficient, CC_i, was calculated using Eqs. (14), (15), and (16) to determine the ranking of KM tools and practices. Table 19 presents the values of the closeness coefficient and the ranking of tools and practices.

Based on Table 19 and the methodology used, “social media” was ranked as the most effective tool among the tools, while “ideation sessions” were ranked as the most effective practice.

Table 17. Normalized weighted fuzzy matrix of KM tools

A^-	A^+	B15	B14	B13	…	B3	B2	B1	
0	1	0.01	0.01	0.01	…	0.01	0.01	0.01	E_1
0	1	0.02	0.03	0.02	…	0.02	0.03	0.02	
0	1	0.03	0.03	0.03	…	0.03	0.03	0.03	
0	1	0.02	0.02	0.02	…	0.01	0.02	0.02	E_2
0	1	0.03	0.03	0.03	…	0.03	0.03	0.03	
0	1	0.05	0.06	0.05	…	0.05	0.06	0.05	
0	1	0.03	0.03	0.04	…	0.02	0.02	0.03	E_3
0	1	0.06	0.07	0.05	…	0.06	0.05	0.06	
0	1	0.10	0.08	0.10	…	0.08	0.10	0.08	
0	1	0.01	0.01	0.01	…	0.02	0.02	0.01	E_4
0	1	0.05	0.04	0.03	…	0.03	0.03	0.04	
0	1	0.05	0.06	0.07	…	0.06	0.06	0.05	
…	…	…	…	…	…	…	…	…	…
0	1	0.02	0.02	0.02	…	0.03	0.02	0.03	S_1
0	1	0.05	0.06	0.04	…	0.06	0.06	0.06	
0	1	0.08	0.07	0.09	…	0.10	0.08	0.09	
0	1	0.02	0.03	0.02	…	0.01	0.01	0.02	S_2
0	1	0.04	0.05	0.05	…	0.04	0.04	0.04	
0	1	0.05	0.06	0.06	…	0.07	0.07	0.07	
0	1	0.01	0.01	0.01	…	0.01	0.01	0.01	S_3
0	1	0.03	0.02	0.03	…	0.03	0.03	0.03	
0	1	0.05	0.04	0.04	…	0.04	0.05	0.04	
0	1	0.01	0.02	0.02	…	0.02	0.02	0.01	S_4
0	1	0.04	0.04	0.04	…	0.05	0.03	0.04	
0	1	0.05	0.06	0.06	…	0.06	0.05	0.06	

Table 18. Normalized weighted fuzzy matrix of KM practices

A^-	A^+	A15	A14	…	A3	A2	A1	
0	1	0.01	0.01	…	0.01	0.01	0.01	E_1
0	1	0.02	0.02	…	0.02	0.02	0.02	
0	1	0.03	0.03	…	0.03	0.03	0.03	
0	1	0.02	0.02	…	0.02	0.01	0.02	E_2
0	1	0.03	0.04	…	0.03	0.04	0.04	
0	1	0.05	0.06	…	0.05	0.06	0.05	
0	1	0.03	0.02	…	0.03	0.04	0.04	E_3
0	1	0.07	0.07	…	0.07	0.05	0.06	
0	1	0.10	0.09	…	0.09	0.08	0.08	
0	1	0.01	0.03	…	0.03	0.01	0.02	E_4
0	1	0.03	0.05	…	0.05	0.04	0.04	
0	1	0.06	0.06	…	0.05	0.06	0.05	
…	…	…	…	…	…	…	…	…
0	1	0.02	0.04	…	0.02	0.02	0.03	S_1
0	1	0.04	0.05	…	0.05	0.07	0.05	
0	1	0.09	0.08	…	0.08	0.08	0.08	
0	1	0.01	0.02	…	0.02	0.01	0.01	S_2
0	1	0.05	0.04	…	0.05	0.04	0.04	
0	1	0.06	0.06	…	0.07	0.06	0.07	
0	1	0.02	0.01	…	0.01	0.02	0.01	S_3
0	1	0.03	0.04	…	0.03	0.03	0.03	
0	1	0.04	0.05	…	0.05	0.04	0.05	
0	1	0.02	0.01	…	0.02	0.01	0.02	S_4
0	1	0.04	0.04	…	0.04	0.04	0.04	
0	1	0.06	0.06	…	0.05	0.06	0.06	

Table 19. Ranking of KM tools and practices

Rank	CC_i	d_j^-	d_j^+	Practices		Rank	CC_i	d_j^-	d_j^+	Tools
10	0.464	0.589	0.680	(B1)		2	0.485	0.604	0.643	(A1)
13	0.456	0.579	0.691	(B2)		15	0.449	0.563	0.690	(A2)
6	0.481	0.603	0.652	(B3)		7	0.477	0.595	0.652	(A3)
9	0.468	0.587	0.667	(B4)		1	0.491	0.629	0.652	(A4)
3	0.488	0.610	0.640	(B5)		13	0.457	0.578	0.687	(A5)
11	0.461	0.580	0.678	(B6)		3	0.482	0.603	0.646	(A6)
4	0.482	0.613	0.660	(B7)		12	0.458	0.567	0.671	(A7)
2	0.489	0.614	0.639	(B8)		5	0.481	0.596	0.642	(A8)
5	0.482	0.597	0.642	(B9)		10	0.466	0.597	0.683	(A9)
14	0.455	0.578	0.692	(B10)		6	0.479	0.597	0.649	(A10)
1	0.490	0.606	0.631	(B11)		11	0.464	0.585	0.674	(A11)
12	0.458	0.572	0.678	(B12)		9	0.468	0.593	0.673	(A12)
7	0.476	0.617	0.679	(B13)		8	0.469	0.585	0.663	(A13)
8	0.474	0.585	0.650	(B14)		4	0.481	0.609	0.658	(A14)
15	0.435	0.550	0.715	(B15)		14	0.452	0.574	0.695	(A15)

4.3 A Sensitivity Analysis to Prioritize KM Tools and Practices

Sensitivity analysis is a powerful tool for verifying the model's robustness and eliminating deviations during the data collection and analysis process [27]. Our sensitivity analysis involved changing the weight of the criterion with the highest weight ("capital cost" in this study) during nine different runs from 0.1 to 0.9. Table 20 and Figure 2 illustrate the ranking of KM tools during these nine runs.

According to Table 20 and Figure 2 the ranking of KM tools does not vary significantly when the weight of "capital cost" is adjusted. Thus, the proposed model appears to be robust based on the results. The rankings of the KM practices during these nine runs are presented in Table 21 and Figure 3.

Table 20. Ranking of KM tools based on sensitivity analysis

Tools	(0.1)	(0.2)	(0.3)	(0.4)	(0.5)	(0.6)	(0.7)	(0.8)	(0.9)
A1	2	4	4	4	4	4	4	4	4
A2	15	14	14	14	14	14	14	14	13
A3	7	7	8	9	9	9	9	9	9
A4	1	1	1	1	1	1	2	3	3
A5	12	13	13	12	12	12	11	11	11
A6	3	2	2	2	2	2	1	1	1
A7	13	12	10	8	7	7	7	7	7
A8	6	5	5	7	8	8	8	8	8
A9	10	8	6	5	5	5	5	5	5
A10	4	6	9	10	10	11	12	12	12
A11	9	11	12	13	13	13	13	13	14
A12	8	10	11	11	11	10	10	10	10
A13	11	9	7	6	6	6	6	6	6
A14	5	3	3	3	3	3	3	2	2
A15	14	15	15	15	15	15	15	15	15

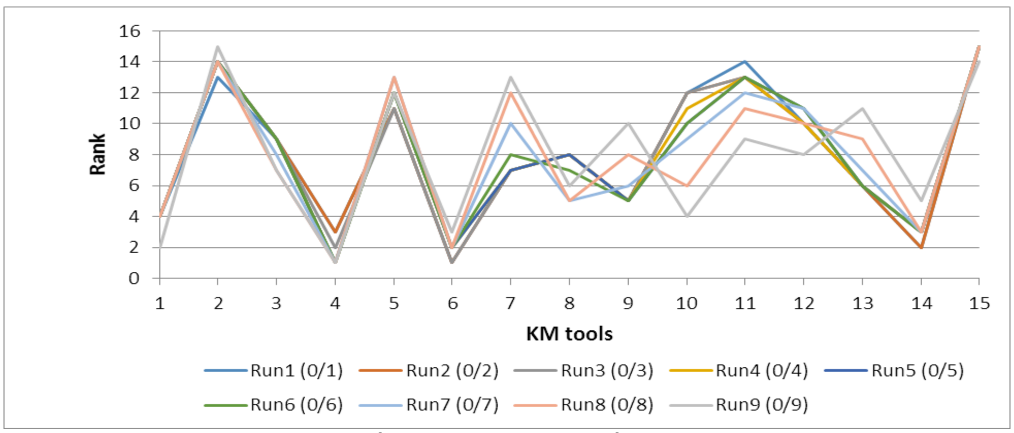

Figure 2. Results of the sensitivity analysis for KM tools

Table 21. Ranking of KM practices based on sensitivity analysis

Practices	(0.1)	(0.2)	(0.3)	(0.4)	(0.5)	(0.6)	(0.7)	(0.8)	(0.9)
B1	11	12	11	11	10	9	9	9	9
B2	12	14	14	14	14	14	14	14	14
B3	4	7	8	9	9	11	12	12	13
B4	10	8	7	7	7	6	6	5	5
B5	3	3	5	5	5	5	5	6	6
B6	9	13	13	13	13	13	13	13	14
B7	6	4	3	2	2	2	2	2	2
B8	2	2	2	4	4	4	4	4	4
B9	5	6	6	6	6	7	7	8	8
B10	14	11	9	8	8	8	8	7	7
B11	1	1	1	1	1	1	1	1	1
B12	13	10	12	12	12	12	11	11	10
B13	7	5	4	3	3	3	3	3	3
B14	8	9	10	10	11	10	10	10	11
B15	15	15	15	15	15	15	15	15	15

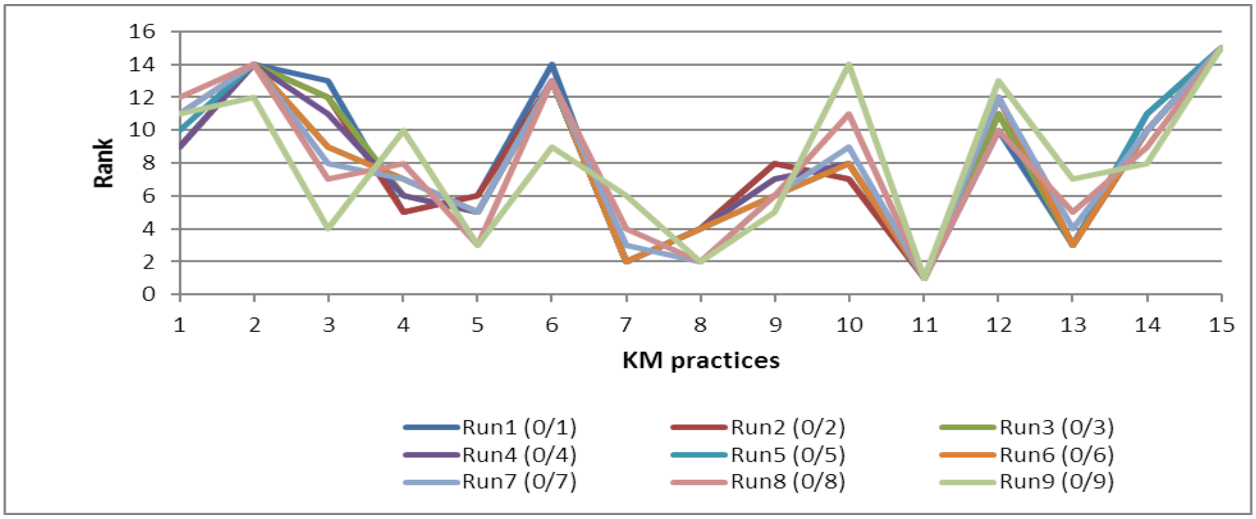

Figure 3. Results of sensitivity analysis for KM practices

Table 21 and Figure 3 demonstrate that the ranking of KM practices does not vary significantly when "capital cost" is adjusted. As a result, the results indicate that the proposed model is robust.

Table 22. Costs associated with implementing each tool

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
B1	51	87	32	64	54	47	44	42	52	92
B2	36	78	23	66	20	32	39	26	100	44
B3	46	100	69	59	20	31	20	75	40	70
B4	34	69	46	83	45	52	74	38	20	60
B5	61	68	22	76	34	28	58	35	99	35
B6	54	24	49	59	80	95	63	90	39	98
B7	42	92	36	32	100	39	95	82	55	32
B8	45	21	36	72	43	98	27	64	35	33
B9	72	100	23	88	92	71	99	63	69	70
B10	83	43	53	97	87	95	74	80	100	86
B11	37	37	71	79	96	81	74	79	22	35
B12	75	52	100	81	57	84	94	22	71	53
B13	93	24	61	85	67	35	38	66	39	31
B14	29	97	75	84	36	82	51	29	74	25
B15	54	34	70	86	76	73	54	37	80	53

4.4 Allocation of KM Tools and Practices to Organizational Knowledge Issues

As a result of the solution of the mathematical programming model for allocation, organizational knowledge issues were assigned a set of KM tools and practices. It is noteworthy that some numbers were generated randomly from a uniform distribution due to the unavailability of some input data. Tables 22 to 28 present the input parameters of the integer bi-objective programming model. In the final step, the proposed integer programming model was solved using GAMS 24.3 and CPLEX.

Table 23. The cost of implementing each practice for each problem

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
A1	71	97	53	53	45	74	49	93	64	70
A2	99	49	36	100	47	58	57	81	31	29
A3	33	40	20	46	56	95	49	58	43	98
A4	43	61	93	52	63	32	25	52	28	97
A5	21	40	27	59	45	22	96	82	95	68
A6	81	66	35	70	24	66	40	64	43	73
A7	25	37	43	39	30	87	71	51	46	95
A8	24	87	26	100	87	59	26	100	68	23
A9	40	31	91	77	49	91	73	61	38	32
A10	49	95	96	100	33	63	52	51	81	52
A11	64	64	51	85	92	69	26	49	73	38
A12	34	31	96	65	71	65	89	51	40	81
A13	27	82	50	49	47	40	24	31	95	84
A14	85	24	91	94	56	80	30	25	46	28
A15	32	80	24	47	20	92	93	32	21	71

Table 24. Accessibility level of each tool for each problem

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
A1	0.32	0.89	0.89	0.22	0.9	0.55	0.4	0.46	0.71	0.49
A2	0.66	0.52	0.86	0.48	0.93	1	0.34	0.58	0.21	0.55
A3	0.7	0.97	0.64	0.61	0.28	0.94	0.76	0.71	0.68	0.85
A4	0.99	0.69	0.68	0.59	0.55	0.3	1	0.95	0.99	0.66
A5	0.93	0.59	0.74	0.72	0.98	0.39	0.28	0.97	0.64	0.88
A6	0.91	0.62	0.57	0.34	0.91	0.66	0.9	0.73	0.59	0.72
A7	0.76	0.95	0.3	0.38	0.82	0.33	0.89	0.56	1	0.51
A8	0.31	0.68	0.58	0.3	0.64	0.4	0.23	0.37	0.23	0.86
A9	0.97	0.38	0.82	0.76	0.38	0.31	0.59	0.83	0.25	0.79
A10	0.29	0.71	0.28	0.36	0.77	0.44	0.9	0.78	0.37	0.69
A11	0.4	0.53	0.33	0.89	0.89	0.29	0.78	0.71	0.38	0.69
A12	0.55	0.68	0.54	0.37	0.58	0.8	0.73	0.27	0.42	0.72
A13	0.33	0.76	0.29	0.41	0.54	0.91	0.76	0.33	0.69	0.4
A14	0.82	0.58	0.48	0.82	0.43	0.59	0.28	0.82	0.79	0.75
A15	0.63	0.75	0.73	0.3	0.6	0.87	0.85	0.3	0.42	0.33

Table 25. Accessibility level of each practice for each problem

P10	P9	P8	P7	P6	P5	P4	P3	P2	P1	
0.64	0.62	0.65	0.64	0.45	0.31	0.3	0.28	0.58	0.27	B1
0.48	0.77	0.61	0.33	0.7	0.52	0.51	0.91	0.65	0.66	B2
0.69	0.58	0.85	0.62	0.21	0.51	0.55	0.27	0.63	0.99	B3
0.51	0.41	0.35	0.38	0.66	0.52	0.58	0.24	0.63	0.28	B4
0.25	0.5	0.84	0.66	0.56	0.52	0.3	0.96	0.99	0.31	B5
0.26	0.87	0.42	0.49	0.77	0.41	0.33	0.95	0.22	0.46	B6
0.93	0.74	0.98	0.21	0.4	0.3	0.55	0.95	0.54	0.29	B7
0.26	0.81	0.97	0.54	0.67	0.98	0.88	0.77	0.3	0.87	B8
0.81	0.31	0.69	0.88	0.93	0.29	0.48	0.33	0.62	0.61	B9
0.99	0.66	0.9	0.59	0.52	0.65	0.82	0.62	0.25	0.66	B10
0.39	0.37	0.58	0.3	0.21	0.81	0.3	0.99	0.78	0.68	B11
0.75	0.78	0.78	0.68	0.35	0.25	0.44	0.48	0.62	0.45	B12
0.5	0.74	0.52	0.68	0.45	0.71	0.56	0.82	0.29	0.23	B13
0.53	0.94	0.54	0.85	0.48	0.46	0.78	0.98	0.54	0.24	B14
0.4	0.47	0.25	0.85	0.61	0.94	0.26	0.31	0.35	0.74	B15

Table 26. The weight of KM tools and practices

Tools	CC_I	Practices	CC_I
A1	0.485	B1	0.464
A2	0.449	B2	0.456
A3	0.477	B3	0.481
A4	0.491	B4	0.468
A5	0.457	B5	0.488
A6	0.482	B6	0.461
A7	0.458	B7	0.482
A8	0.481	B8	0.489
A9	0.466	B9	0482
A10	0.479	B10	0.455
A11	0.464	B11	0.490
A12	0.468	B12	0.458
A13	0.469	B13	0.476
A14	0.481	B14	0.474
A15	0.452	B15	0.435

Table 27. The maximum number of tools allowed to be assigned to each problem

P10	P9	P8	P7	P6	P5	P4	P3	P2	P1
1	2	3	2	2	4	1	2	3	3

Table 28. The maximum number of practices allowed to be assigned to each problem

P10	P9	P8	P7	P6	P5	P4	P3	P2	P1
4	3	2	3	2	2	2	2	4	1

A budget of 500 million Rials was determined to be available to the organization. Furthermore, the threshold limit for the efficacy of tools and practices was set at 3 and 3, respectively.

4.4.1 Results obtained from solving the model

This study utilized GAMS optimization software and the CPLEX solver to solve the model. In addition, the execution time of the model solution was 52.942 seconds. Following the solution of the model, it was determined how each tool and practice should be allocated to knowledge issues, as shown in Table 29. In general, 200 points were generated on the Pareto front as a result of solving the model. Table 29 describes the values associated with the objective functions (cost and accessibility level) for each point.

Table 29. The Pareto points derived from the model's solution

10	9	8	7	6	5	4	3	2	1	Point
316	316	316	316	316	316	315	315	315	315	Z1
9.3	9.3	9.3	9.3	9.3	9.3	9.06	9.06	9.06	9.06	Z2
20	19	18	17	16	15	14	13	12	11	Point
319	319	319	319	319	318	318	318	318	316	Z1
9.69	9.69	9.69	9.69	9.69	9.45	9.45	9.45	9.45	9.3	Z2
30	29	28	27	26	25	24	23	22	21	Point
326	324	324	323	323	323	323	319	319	319	Z1
10.02	9.91	9.91	9.85	9.85	9.85	9.85	9.69	9.69	9.69	Z2
40	39	38	37	36	35	34	33	32	31	Point
333	331	331	331	330	330	327	327	326	326	Z1
10.38	10.24	10.24	10.24	10.15	10.15	10.08	10.08	10.02	10.02	Z2
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
160	159	158	157	156	155	154	153	152	151	Point
454	453	451	451	450	447	447	446	446	443	Z1
14.28	14.25	14.23	14.23	14.15	14.11	14.11	14.04	14.01	13.98	Z2
170	169	168	167	166	165	164	163	162	161	Point
466	463	463	462	462	459	459	457	456	455	Z1
14.61	14.57	14.57	14.51	14.48	14.44	14.44	14.4	14.35	14.32	Z2
179	178	177	176	175	174	173	172	171	170	Point
475	474	473	472	472	470	467	467	467	466	Z1
14.91	14.88	14.85	14.81	14.81	14.74	14.71	14.71	14.71	14.61	Z2
190	189	188	187	186	185	184	183	182	181	Point
488	487	486	485	483	482	482	479	479	479	Z1
15.28	15.25	15.21	15.18	15.16	15.11	15.11	15.04	15.04	15.04	Z2
200	199	198	197	196	195	194	193	192	191	Point
499	499	498	497	495	494	492	492	491	489	Z1
15.64	15.64	15.55	15.52	15.5	15.45	15.41	15.41	15.37	15.33	Z2

Figure 4 illustrates that as costs increase, the accessibility level of tools and practices increases as well. Based on the values obtained for the objective functions, point number 200 appears to be the most appropriate point for management. At this point, $Z_1 = 499$ and $Z_2 = 15.64$. The representation of this point reveals how tools and/or practices are allocated to knowledge-related issues. A list of tools and practices related to organizational knowledge issues is presented in Table 30.

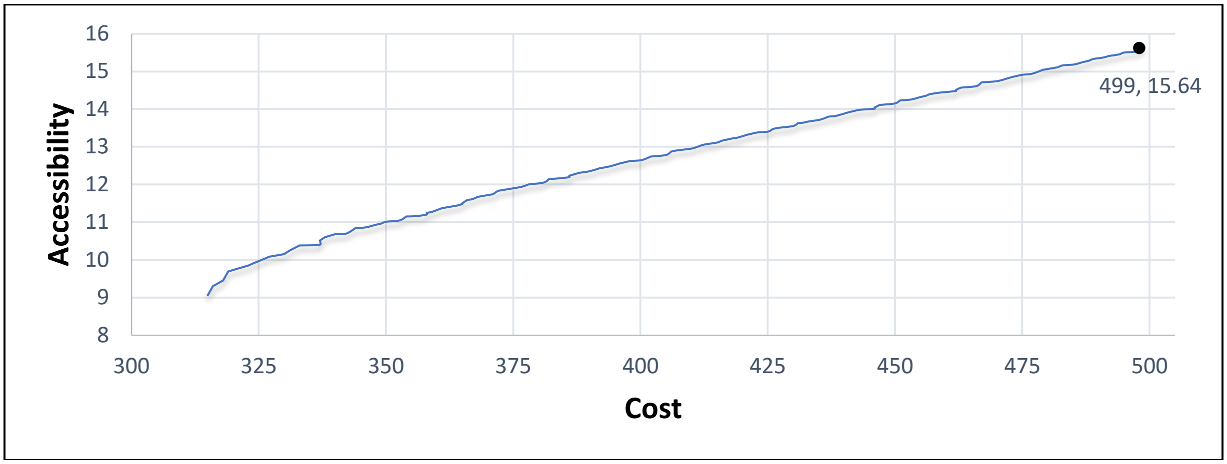

Figure 4. The resulting Pareto front based on cost and accessibility

Table 30. Tools and practices allocated to organizational knowledge problems

KM-related problems	Tools /Practices (techniques)
File and information search and retrieval	Expert systems, Wikis, Document management system
Knowledge creation	Data mining, Ideation sessions, Expert forum
Knowledge accumulation	Cloud Computing, After action review, Wikis
Knowledge transfer	Knowledge modeling, Storytelling
Knowledge valuation	After action review, Classification, Content management systems
Collaboration and knowledge sharing	Social Media, Coaching, Expert forum, Audio and video conferencing
Decision-making	Brainstorming, Data mining, Classification
The conversion of tacit knowledge into explicit knowledge	Decision Support System, Seminar
Organizational knowledge security	Document management system, Data management systems
Knowledge benchmarking	Podcasts and videocasts, Knowledge modeling

4.4.2 Allocation Model Sensitivity Analysis

Under different scenarios, threshold values for the efficacy of tools as well as threshold values for the efficacy of practices were considered to perform a sensitivity analysis of the model and to determine how it responds to changes in input parameters. Changes of $\pm 10\%$, $\pm 20\%$, and $\pm 30\%$ were applied. Table 31 reports the amount of change in the objective functions after solving the model at Pareto point number 100.

As shown in Table 31, when the threshold limit for the degree of efficacy of the tools and the threshold limit for the degree of efficacy of the practices are increased or decreased, the objective functions are also affected. Therefore, the proposed model displays a good response to the changes in parameters, which proves that the model is highly effective against the changes in parameters.

Table 31. Sensitivity analysis of the proposed model

Objective functions		Parameter values by applying changes	Changes in percent	Parameters' default values	Scenarios
Z_2	Z_1				
10.88	330	TM=2.1	-30%	TM=3	Scenario 1
		TN=2.1		TN=3	
10.69	331	TM=2.4	-20%	TM=3	Scenario 2
		TN=2.4		TN=3	
11.54	357	TM=2.7	-10%	TM=3	Scenario 3
		TN=2.7		TN=3	
12.31	388	TM=3	0	TM=3	Scenario 4
		TN=3		TN=3	
11.92	376	TM=3.3	+10%	TM=3	Scenario 5
		TN=3.3		TN=3	
12.65	410	TM=3.6	+20%	TM=3	Scenario 6
		TN=3.6		TN=3	
13.23	440	TM=3.9	+30%	TM=3	Scenario 7
		TN=3.9		TN=3	

5. Analysis and Discussion

In this study, after identifying the main criteria and sub-criteria for evaluating KM tools and practices, the best-worst method (BWM) was employed to rank the main criteria and sub-criteria. The main criteria were ranked in the following order: "Stakeholder satisfaction > knowledge efficacy > cost > application". In the evaluation of KM tools and practices, stakeholder satisfaction was deemed to be the most important criterion. As per the ranking of the stakeholder satisfaction criterion sub-criteria, "customers > staff > suppliers > shareholders," the stakeholder satisfaction criterion gives the highest weight to customers, while the stakeholder satisfaction criterion assigns the lowest weight to shareholders. Based on the ranking of the sub-criteria related to the efficacy criterion, "knowledge transfer > knowledge diffusion > knowledge accumulation > knowledge creation" indicates that knowledge transfer is the highest weighted sub-criteria for the efficacy criterion, while knowledge creation is the lowest weighted sub-criteria. The sub-criteria related to the cost criterion were ranked as follows: capital cost > operating cost > development cost, indicating that capital cost has the highest weight for the cost criterion, while development cost has the lowest weight. The ranking of the sub-criteria related to the application criterion included "integration > personalization > collaboration and communication > tracking and monitoring", which indicates that integration is the most important application criterion, while tracking and monitoring are the least important.

A fuzzy TOPSIS method was then used to rank KM tools and practices. According to the closeness coefficient, CC_i, the tools ranked include "social media > blogs > content management system > decision support system > podcasts and videocasts > audio and video conferencing > KM evaluation tools > data management system > data mining > document management system > crowdsourcing system > wikis > expert systems > cloud computing > advanced search tools".

According to the closeness coefficient, CC_i, the practices are ranked as follows: "ideation sessions > knowledge discovery interview > after action review > knowledge modeling > brainstorming > classification > job rotation > learning review > coaching > knowledge café > knowledge mapping > seminar > expert forum > storytelling > collaborative assistance.

Finally, KM tools and practices were allocated to organizational knowledge issues using a bi-objective mathematical programming model. Based on tools, there were fifteen tools approved by the experts, of which eleven were allocated to organizational knowledge issues as follows:

- Social media was allocated to "collaboration and knowledge sharing".
- The expert system was allocated to "file and information search and retrieval".
- The content management system was allocated to "knowledge valuation".
- Wikis were allocated to "file and information search and retrieval" and "knowledge accumulation".
- Podcasts and videocasts were allocated to "knowledge benchmarking".
- The document management system was allocated to "file and information search and retrieval" and "organizational knowledge security".
- Audio and video conferencing were allocated to "collaboration and knowledge sharing".
- Data mining was allocated to "knowledge creation" and "decision-making".
- The data management system was allocated to "organizational knowledge security".
- The decision support system was allocated to "the conversion of tacit knowledge into explicit knowledge".
- Cloud computing was allocated to "knowledge accumulation".

According to practices, there were fifteen practices approved by the experts, of which nine were allocated to organizational knowledge issues as follows:

- The expert forum was allocated to "knowledge creation" and "collaboration and knowledge sharing".
- The classification was allocated to "knowledge valuation" and "decision making".
- Coaching was allocated to "collaboration and knowledge sharing".
- The after-action review was allocated to "knowledge accumulation" and "knowledge valuation".
- Knowledge modeling was allocated to "knowledge transfer" and "knowledge benchmarking".
- Brainstorming was allocated to "decision making".
- Storytelling was allocated to "knowledge transfer".
- Ideation sessions were allocated to "knowledge creation".
- The seminar was allocated to the "conversion of tacit knowledge into explicit knowledge".

6. Conclusion

In today's world, many organizations implement KMSs. There is however a problem with selecting the right KMS for these organizations. Therefore, the solution to this problem requires a suitable approach. This study aimed to develop a hybrid MCDM and MODM model to allow corporate managers to select KM tools and practices according to the specific conditions of their organization. By reviewing the literature and interviewing experts, this study identified fifteen KM tools and fifteen KM practices, four main criteria, fifteen sub-criteria, and ten organizational knowledge issues. As part of the evaluation of KM tools and practices, the BWM was used to determine the weight of the main criteria and sub-criteria. KM tools and practices were ranked using the fuzzy TOPSIS method. As a result, a bi-objective mathematical programming model was developed to allocate KM tools and practices to organizational knowledge issues in a systematic manner. "Stakeholder satisfaction" was identified as the most critical criterion for evaluating KM tools and practices. "Capital cost", "knowledge transfer", and "customers" were given the highest weight among the sub-criteria. "Social media" and "ideation sessions" were ranked as the most important tools and practices, respectively. Finally, eleven tools were allocated to knowledge issues out of the fifteen tools approved by experts. Out of fifteen practices approved by experts, nine were also allocated to knowledge issues.

Among the limitations of the research, it can be mentioned that the experts do not master the questionnaires of decision-making techniques, the lack of accuracy in completing the questionnaires, and the lack of access to the experts.

Researchers suggest the following directions for future research:

- This study identified "stakeholder satisfaction" as the most important criterion. It is recommended that future research identify the factors that have a greater impact on stakeholder satisfaction and examine this issue in more detail.
- Based on the viewpoints of experts, we developed a theoretical framework for this study. This theoretical framework can be utilized in other case studies and compared with the results of this study.
- It is recommended that future research consider other criteria for evaluating KM tools and practices.
- It may be possible to solve this problem using other MCDM methods, such as VIKOR, ANP, ELECTERE, and the like, and compare the results with those of this study.
- The proposed multi-objective mathematical programming model can be solved using a variety of other methods, including the LP-metric method, ideal access method, weighted sum method, etc., and their results can be compared with those of the present study.
- In this study, KM tools and practices were allocated based on two objectives: cost and accessibility. Future research may develop the model to address other objectives, such as increased organizational productivity, reduced risk, etc.

Conflict of interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Aghaie, M., Nasrollahi, M., fathi, M. R., & salehi, S. (2019). Investigating the Role of Knowledge Management System in Open Innovation and Knowledge Management Capacity in IOT (Case Study: Domestic Appliance Manufacturing Companies). *Quartely Journal of Logistics & Human Resources Management*, 1398(53), 1-18.
2. Agrawal, N. (2021). Modeling enablers of knowledge management process using multi criteria decision making approach, *VINE Journal of Information and Knowledge Management Systems*, 51(3), 389 417.
3. Alavi, M., & Leidner, D. (2001). Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues. *MIS quarterly*, 25(1), 107-136.
4. Bhatt, G.D. (2001). Knowledge management in organizations: examining the interaction between technologies, techniques, and people, *Journal of Knowledge Management*, 5(1), 68-75.
5. Bowman, B.J. (2002). Building Knowledge Management Systems. *Information System Management*, 19, 32-40.
6. Büyüközkan, G. and Feyzioglu, O., (2008). A Decision Framework for the Evaluation of the KM Tools. *Management of Engineering & Technology* 2008. Picmet 2008.1075-1084.
7. Büyüközkan, G., Parlak, I.B., & A. Tolga C. (2016). Evaluation of Knowledge Management Tools by Using An Interval Type-2 Fuzzy TOPSIS Method, *International Journal of Computational Intelligence Systems*, 9(5), 812-826.
8. Centobelli, P., Cerchione, R., & Esposito, E. (2017). Aligning Enterprise Knowledge and Knowledge Management Systems to Improve Efficiency and Effectiveness Performance: A Three-dimensional Fuzzy-based Decision Support System. *Expert Systems With Applications*, 91, 107-126.
9. Chang, P.C., Liu, C.H., Lai, R.K., (2008). A fuzzy case-based reasoning model for sales forecasting in print circuit board industries. *Manager Systems with Applications*, 34 (3), 2049–2058.
10. Chankong, V., & Haimes, Y. Y. (2008). Multiobjective decision making: theory and methodology. Courier Dover Publications.
11. Chen, D., Faibil, D. & Agyemang, M. (2020). Evaluating critical barriers and pathways to implementation of e-waste formalization management systems in Ghana: a hybrid BWM and fuzzy TOPSIS approach. *Environmental Science and Pollution Research*, 27**,** 44561–44584.
12. Chu, TC., Lin, YC. A (2003). Fuzzy TOPSIS Method for Robot Selection. *Int J Adv Manuf Technol*, 21, 284–290.

13. Corso, M., Martini, A., Pellegrini, L., & Paolucci, E. (2003). Technological and Organizational Tools for Knowledge Management: In Search of Configurations. *Small Business Economics*, 21(4), 397-408.
14. Davis, L., Williams, G. (1994). Evaluating and Selecting Simulation Software Using the Analytic Hierarchy Process, *Integrating Manufacturing System*, 5, 23-32.
15. Dawson, R.J., (2007). Knowledge Management Implementation Problems and How to Overcome Them, Proceedings of Software Quality Management XV: Improving Quality in Computing Education, Berki, Nummenmmaa, Sunley, Ross and Staples, BCS, Software Quality Management 2007, Stafford, UK, April 2007, 341-352, ISBN: 978-1-902505-96-1.
16. Dorfeshan, Y., Tavakkoli-Moghaddam, R., Jolai, F., & Mousavi, S. (2021). A New Data-driven and Knowledge-driven Multi-criteria Decision-making Method. *Journal of AI and Data Mining*, 9(4), 543-554.
17. Ehrgott, M. (2005). Multicriteria optimization (Vol. 491). Springer Science & Business Media.
18. Eslamkhah, M., & Seno, S.M.A. (2019) Identifying and Ranking Knowledge Management Tools and Techniques Affecting Organizational Information Security Improvement, *Knowledge Management Research & Practice*, 17(3), 276 305.
19. Fan, B. Feng, Y. Sun and W. Ou. (2009). Evaluating knowledge management capability of organizations: a fuzzy linguistic method, *Expert Systems with Applications*, 36, 3346–3354.
20. Fathi, M.R., Torabi, M. and Razi Moheb Saraj, S. (2022). The future of apitourism in Iran based on critical uncertainty approach and DEMATEL/COPRAS techniques, *Journal of Tourism Futures*, Vol. ahead-of-print No. ahead-of-print.
21. Fathi, M. R., Sobhani, S. M., Nasrollahi, M., & Abdollahi Nejat, M. (2021). The Effect of Structured Knowledge on the Performance of an Organization. *Health Management & Information Science*, 8(4), 242-247.
22. Fathi, M. R., Sadeghi, M. R., & Khosravi, A. (2020). Assessing the Level of Organizational Readiness to Implement Knowledge Management (Case study: a Military University). *Military Science and Tactics*, 16(53), 5-29.
23. Fink, K., & Ploder, C. (2009). Knowledge management toolkit for SMEs. *International Journal of Knowledge Management*, 5(1), 46-60.
24. Greco, M., Grimaldi, M., Hanandi, M. (2013). How to Select Knowledge Management Systems: A Framework to Support Managers. *International Journal of Engineering Business Management*, 5, 2013.
25. Grimaldi M, Rippa P (2011). An AHP-based framework for selecting knowledge management tools to sustain innovation process. *Knowledge and Process Management*, 18 (1), 45-55.
26. Grimaldi, M., Cricelli, L. (2009). Intangible Asset Contribution to Company Performance: The Hierarchical Assessment Index. *The Journal of Information and Knowledge Management Systems* – VINE, 39 (1), 40-54.
27. Gupta, H., Barua, M.K., (2017). Supplier selection among SMEs on the basis of their green innovation ability using BWM and fuzzy TOPSIS, *J. Clean. Prod*,152, 242–258.
28. Habib M (2011). An Exploratory Analysis of Educational Management for the Universities. *International Journal of Engineering Business Management*, 3(3), 16-24.
29. Haimes, Y. V. (1971). On a bicriterion formulation of the problems of integrated system identification and system optimization. *IEEE transactions on systems, man, and cybernetics*, 1(3), 296-297.
30. Holland, Suzi & Dawson, Ray. (2011). Classification and selection of tools for quality knowledge management. *Software Quality Journal*. 19. 393-409.
31. Holsapple C W, Joshi K D (2002). Knowledge Manipulation Activities: Results of a Delphi Study. *Information & Management*, 39, 477-490.
32. Jamali, A., Faghih, A., Fathi, M. R., & Rostami, F. (2023). A Combined Fuzzy Multi-Criteria Decision Making Framework for Evaluation of Islamic Banks: A Case of MENA Region. *Fuzzy Optimization and Modeling Journal*, 4(2), 49-65.
33. Jenab, K., Khoury, S., & Sarfaraz A.R.(2013).Evaluating Knowledge Management Tools on the Basis of Customization using Fuzzy Approach. *International Journal of Industrial Engineering & Production Research*, 24(4), 247-257.

34. Kaya, R., Salhi, S. & Spiegler, V. A novel integration of MCDM methods and Bayesian networks: the case of incomplete expert knowledge. *Ann Oper Res*, 320, 205–234 (2023).
35. Khajouei, H., Khajouei, R. (2017). Identifying and Prioritizing the Tools/Techniques of Knowledge Management Based on the Asian Productivity Organization Model (APO) to use in Hospitals, *International Journal of Medical Informatics*, 108, 146-151.
36. Kutlu, A. C.,& Ekmekçioğlu, M. (2012). Fuzzy failure modes and effects analysis by using fuzzy TOPSIS-based fuzzy AHP, Expert Systems with Applications, 39(1), 61-67, ISSN 0957-4174.
37. Lai, Y.J., Liu, T.Y., Hwang, C.L., (1994). Topsis for MODM, *Eur. J. Oper. Res*, 76 (3), 486–500.
38. Li, M., Jin, L., Wang, J. (2014). A new MCDM method combining QFD with TOPSIS for knowledge management system selection from the user's perspective in intuitionistic fuzzy environment. *Applied Soft Computing*, 21, 28-37.
39. Liebowitz, J., (2000). Building organizational intelligence: A knowledge management primer. US: CRC Press.
40. Liu, W.; Wang, Y.; Li, L. (2023). Research on the optimal aggregation method of judgment matrices based on spatial steiner-weber point, *J. Syst. Sci. Complex*, 36, 1228–1249.
41. Maiden, N A., Ncube, C. (1998). Acquiring Cost Software Selection Requirements. IEEE Software. 15: 46-56.
42. Mohamed, M.A. and Mohamed, M.S., (2008). Compendious reflections on VINE's technology inquiries. *VINE*, 38(4), 388-397.
43. Nafei, A., Huang, C. Y., Chen, S. C., Huo, K. Z., Lin, Y. C., & Nasseri, H. (2023). Neutrosophic Autocratic Multi-Attribute Decision-Making Strategies for Building Material Supplier Selection. *Buildings*, 13(6), 1373.
44. Nezhadkian, M., Azimi, S. M., Ferro, A., & Nafei, A. H. (2023). A model for new product development in business companies based on grounded theory approach and fuzzy method. *Journal of Computational and Cognitive Engineering*, 2(2), 124-132.
45. Ngai, E.W.T. and Chan, E.W.C., (2005). Evaluation of knowledge management tools using AHP. *Expert Systems with Applications*, 29(4), 889-899.
46. Nonaka I, Konno N (1998). The Concept of Ba: Building a Foundation for Knowledge Creation. *California Management Review*, 40, 116-132.
47. Orlikowski W J, Iacono C S (2001). Research Commentary: Desperately Seeking the IT, in IT Research a Call to Theorizing the IT Artifact. *Information System Research*, 12,121–134.
48. Oztaysi B (2014). A decision model for information technology selection using AHP integrated TOPSIS-Grey: The case of content management systems. *Knowledge-Based Systems*, 70, 44–54.
49. Pourrafiee, M., Nafei, A., Banihashemi, S., & Pourmohammad Azizi, S. (2020). Comparing entropies in portfolio diversification with fuzzy value at risk and higher-order moment. *Fuzzy Information and Engineering*, 12(1), 123-138.
50. Rajabpour, E., Ghorbanpur, A., Fathi, M. R., & Sobhani, S. M. (2022). Gamification Driver Soft Modelling of Learning Management Systems in Covid-19 Pandemic. *International Journal of Knowledge Processing Studies*, 2(4), 27-42.
51. Rezaei, J. (2015). Best-worst multi-criteria decision-making method. *Omega*, 53, 49-57.
52. Rezaei, J. (2016). Best-worst multi-criteria decision-making method: Some properties and a linear model. *Omega*, 64, 126-130.
53. Ronaghi, M. H., Zeinodinzadeh, S., & Alambeladi, S. (2019). Identification and Ranking the Factors Affecting the Knowledge Management Implementation Using Metasynthesis Method. *Library and Information Sciences*, 22(3), 112-135.
54. Ruano, M., Huang, C. Y., Nguyen, P. H., Nguyen, L. A. T., Le, H. Q., & Tran, L. C. (2023). Enhancing Sustainability in Belize's Ecotourism Sector: A Fuzzy Delphi and Fuzzy DEMATEL Investigation of Key Indicators. *Mathematics*, 11(13), 2816.
55. Salisbury M W (2003). Putting Theory Into Practice to Build Knowledge Management Systems. *Journal of Knowledge Management*, 7, 128-114.

56. Shih, H.-A., & Chiang, Y.-H. (2005). Strategy alignment between HRM, KM, and corporate development. *International Journal of Manpower*, 26(6), 582-603.
57. Singh M, Sarfaraz A, Jenab K, Gandhi J S (2013). Selection of knowledge management tools using integrated AHP-QFD model. *Int. J. Management and Decision Making*, 12(4), 2013.
58. Sun, C. C. (2010). A performance evaluation model by integrating fuzzy AHP and fuzzy TOPSIS methods. *Expert systems with applications*, 37(12), 7745-7754.
59. Tallon, P. (2007). A process-oriented perspective on the alignment of information technology and business strategy. *Journal of Management Information Systems*, 24(3), 227-268.
60. Tseng, S.-M. (2008). Knowledge management system performance measure index. *Expert systems with Application*, 34, 734-745.
61. Tyndale P (2002). A Taxonomy of Knowledge Management Software Tools: Origins and Applications. *Evaluation and Program Planning*, 25, 183-190.
62. Weiss, J., & Anderson, D. (2004). Aligning technology and business strategy: Issues & frameworks, a field study of 15 companies. *Proceedings of the Hawaii International Conference on System Sciences*, 37, 3467-3476.
63. Wei C-C, Tai C-C, Lee S-C, Chang M-L. (2023). Assessing Knowledge Quality Using Fuzzy MCDM Model. *Mathematics*, 11(17):3673.