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A Markov-based assessment of Knowledge Management Models at Universities

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ABSTRACT

Purpose: There is a growing interest in knowledge management (KM) within academia and universities. Despite the high level of understanding and appreciation for Knowledge Management Models (KMMs) and their relevance to knowledge at universities, the role of KM models and approaches is rarely investigated. This study examines and ranks factors associated with KMM at universities in Tehran, Iran. **Methodology:** This study employs a mixed method approach, combining qualitative techniques (a three-phase Delphi method) and quantitative methods (Best-Worst method [BWM] and MARKOV). MARKOV is applied here as an integrated Machine Learning-Markov approach to enhance the performance of KM implementation at universities. The relevant factors are processed through a Markov-based model, enabling the identification of future KMM factors. BWM is utilized to determine first-stage weights, and the Markovian weighted average of KMM factors is considered the optimal result. A questionnaire with open-ended questions is employed to collect accurate data, with thirty experts selected to participate in the survey. **Findings:** Nine factors were extracted from the literature review and Delphi method. The Markov model is employed to trace the priorities of KMM factors, serving as a predictive tool for modeling KM factors. The final weights of the factors are closely ranked as follows: (1) Information Technology; (2) applying knowledge; (3) structure; (4) Measuring knowledge; (5) culture; (6) Sharing knowledge; (7) leadership style; (8) Maintaining knowledge; and (9) Collecting knowledge. **Originality:** To the best of the authors' knowledge, this is the first assessment and prediction of KMM factor usage at universities in Iran, an important country in the Middle East. The authors introduce new and customized factors for KMM. Predicting behaviors over time assists managers and university decision-makers in recognizing the fundamental dimensions of KM success. This study contributes by identifying and predicting the behaviors of KM context factors at universities in Iran.

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1. Introduction

Knowledge is considered an essential factor for improving performance and gaining a competitive advantage in organizations. According to Evers and Gerke (2005), knowledge management (KM) has been widely practiced internationally since its introduction in the 1980s. The significance of KM and the knowledge economy is comprehensively acknowledged in public and private organizational documents, particularly in ministry plans, government offices, and related documents. However, the level of KM understanding and implementation in Iran, both in theory and practice, is not considered high. In addition to teaching, university lecturers should focus on scientific research. KM plays a vital role in universities as a fundamental practice and a supporting element for enhancing the university's brand and position. Numerous studies on KM have been conducted worldwide in recent years (Ferraresi et al., 2012; Putra & Febriani, 2017; Gunjal, 2019). Most of these studies concentrate on topics such as capturing, creating, maintaining, sharing, developing, publishing, and utilizing knowledge (Naser et al., 2016; Rivera, 2016), whether individually or in organizational teams, to improve efficiency. Additionally, emerging topics related to KM systems, such as the community of practice (CoP), have been discussed. In this study, the main objective is to conduct a comprehensive and systematic review of KM and Knowledge Management Models (KMMs) at universities, collecting and integrating the most critical factors.

Furthermore, this study aims to identify the key factors in KMMs utilized at universities in Iran. Initially, a literature review approach was employed to identify and analyze the major themes of KM in universities. Subsequently, the Delphi method was used to present the literature findings to the participants, who then shortlisted and combined the factors based on the specific features of KMMs in Iranian universities. The Best-Worst method (BWM) was then applied to calculate the weights of the criteria. Finally, the Markov model was used to determine the priorities of KMM factors, serving as a predictive tool for modeling KM factors. The utilization of a Markov model simplifies the identification of patterns in KMM factors, as it can track changes and shifting preferences of universities over time.

The main contributions of this study are summarized as follows:

- Identification of KMM factors at universities: Limited studies have been conducted on KM models specific to universities in Iran. This study collects, integrates, shortlists, customizes, and finalizes the factors of KMM through a literature review and the Delphi fuzzy method.
- Application of the Best-Worst method (BWM) for determining initial weights.
- Consideration of the Markovian weighted average of KMM factors as an outcome for identifying optimal factors.
- Prediction of future KMM factors through an integrated Machine Learning-Markov approach.
- Prediction of behavioral changes over time to assist managers and university decision-makers in recognizing the fundamental dimensions of KMM success.

Moreover, as a contribution, we have focused on identifying patterns for KMM at universities in Tehran, Iran. By predicting behaviors over time, this study aims to assist managers in university departments in recognizing the fundamental dimensions of KM success. This research contributes by identifying and predicting the behaviors of KM context factors at universities in Tehran, Iran. In general, our objective is to assess and predict the usage of KMM factors at universities in Iran, which is an important country in the Middle East.

Furthermore, the utilization of Markov in this study offers a more dynamic perspective to managers and stakeholders compared to other methods, as it demonstrates changes in the model over time.

2. Literature Review

Knowledge is recognized as a crucial resource for organizations, contributing to long-term performance (Sergeeva and Andreeva, 2016; Tangaraja et al., 2016). In recent decades, knowledge management (KM) has been extensively researched and implemented in universities and organizations (Kassaneh et al., 2021). KM is a systematic approach to identifying, sharing, managing, transferring, applying, and updating information (Singh et al., 2012). It is applied across various fields and disciplines, considering the diverse cultures, values, backgrounds, and management practices involved.

The rapid pace of knowledge change has drawn significant attention. Knowledge is increasingly

recognized as a vital catalyst for action, a strategic and valuable asset in universities. With technology and science experiencing extraordinary changes (Nevo & Chan, 2007) and innovation accelerating the rate of learning, organizations and corporations have become more competitive. Therefore, universities, as knowledge-intensive organizations, need to examine knowledge management models to thrive in the competitive environment and outperform their rivals.

KM encompasses numerous procedures that facilitate the creation, development, sharing, codification, and application of knowledge to enhance effectiveness in corporations and organizations (Rodrigues, 2016). Sharing best practices adopted in past events is one of the main drivers of organizational success (Pereira et al., 2022). However, due to the various interpretations, there is no clear-cut definition of knowledge management. Nevertheless, KM plays a vital role in integrating business processes and knowledge (Sarnikar & Deokar, 2017). It is widely acknowledged as a deep-rooted topic and a prominent area of discussion for enhancing organizational performance (Abeh et al., 2022).

According to Asadzadeh et al. (2020), in the face of increasing international competition, a deep understanding of knowledge management and its contributing factors empowers organizations, industries, and universities to enhance operational excellence. It should be recognized that KM is critical for skill improvement among individuals in light of recent findings and advancements within universities (Ramesh & Sivakumar, 2021). Furthermore, Asadzadeh et al. (2019) highlighted that sharing knowledge, including issues, incidents, and near misses, fosters a culture of trust and attention.

KM is applied in organizations to improve the effectiveness and efficiency of business processes, achieve knowledge strategies, and sustain organizational performance (Kordab et al., 2020). Organizations with a strong learning culture can encourage knowledge management and robust employee participation (Mansour & Abuarqoub, 2020), which have a positive impact on employee attitudes, behaviors, and organizational performance (Djamil et al., 2018). Active employee participation can enhance company performance (Astuti et al., 2019).

The management of knowledge collected by the organization, for the utilization of existing information, is considered a driver for innovation (Ferraris et al., 2017). The role of KM extends beyond the efficiency of internal and external knowledge allocation within organizations; it also encompasses the utilization of the company's innovative potential at multiple levels (Shujahat et al., 2019). The use of advanced tools is widely emphasized as a means to enhance competitiveness, facilitate access to knowledge flows, and highlight the degree of relationship between valuable knowledge in different departments of an organization (Ghezzi & Cavallo, 2020; Gupta & Bose, 2019; Huesig & Endres, 2019; Nagy et al., 2018; Pappas et al., 2018; Raut et al., 2019; Tian, 2017). Moreover, knowledge expresses its maximum potential when it is exploited by the organization (Usai, Scuotto, Murray, Fiano, & Dezi, 2018), through internal and external sharing processes, which enrich the company’s know-how (Bogers et al., 2018; Huesig & Endres, 2019; Pappas et al., 2018; Raut et al., 2019; Seele, 2017; Xia et al., 2017).

There is a developing interest in knowledge management (KM) within academia and universities. Despite the high level of understanding and appreciation for KMMs and considering knowledge at the universities, the role of KM models and approaches are rarely investigated.

Smith (2001) is highly discussed and used in different studies compared with other KM definitions. Smith (2001) states that KMM includes: (1) collection and accumulation of knowledge; (2) organizing, sharing, and knowledge application to an organization’s activities; (3) sharing and protection of knowledge creators' interests; and (4) having some metrics for employees' motivation to protect valuable knowledge. The fundamental activities in KM include: seeking, collecting, and sharing knowledge/employees Motivation/transforming and sharing knowledge among the team and protecting the knowledge workers' and creators' rights.

Miltiadis et al. (2003) indicated that researchers split KM into four elements and sequences: (1) accumulating; (2) transferring; (3) using; and (4) preserving knowledge. Nonetheless, Mehta (2008) asserted that having KM in many activities of an organization is necessary. Correspondingly, Lee et al. (2001) explained KM alongside factors including culture, strategy, leadership, information technology, and motivational tools for creating knowledge products.

Pinho et al. (2012) identified opportunities and barriers by considering society, technology, individuals, and organizations. The study suggested four processes for KM: (1) acquisition, (2) creation, (3) distribution, and (4) knowledge transfer. Martín-de Castro et al. (2011) surveyed 221

sample firms in Finland, China, and Russia, examining the KM process in these steps: creating knowledge, storing knowledge, sharing knowledge, and acquiring knowledge. Based on the studies, KM factors have a positive effect on innovation. Additionally, the role of the knowledge creation process in relation to the three remaining KM processes and innovation is significant.

Bhatti et al. (2011) and Rašula et al. (2012) demonstrated that enhancing the implementation of KM activities leads to higher organizational efficiency. Du Plessis (2007) emphasized the importance of the KM process in creating new knowledge and ensuring the efficient use of knowledge in the organization. The KM process facilitates other vital organizational procedures by enhancing the amount of knowledge needed by members and accelerating the distribution of organizational knowledge. Thus, KM has a profound influence on transforming knowledge power into innovative processes (Du Plessis, 2007; Huang & Li, 2009; Nonaka & Takeuchi, 1995). Wigg (1993) introduced six phases of a KM cycle related to organizational KM: (1) creating, (2) presenting, (3) combining, (4) transforming, (5) publishing, and (6) using knowledge.

Nonetheless, Wee and Chua (2013) proposed a three-step model to moderate the KMM as follows: (1) creation, (2) sharing, and (3) knowledge reuse. Bigliardi et al. (2014) stated that there is no single standard KM system applicable to all organizations, implying that organizations should adopt various KM processes. Asadzadeh et al. (2020) argue that with the rapid increase in international competition, in-depth knowledge management and its contributing factors will enable organizations and industries to enhance their operational excellence. Moreover, Asadzadeh et al. (2019) highlighted that sharing knowledge such as issues, incidents, and near misses fosters a culture of trust and attention. Based on the studies, there are two similarities among the 20 participants. Firstly, the KM process was cyclically formed in all organizations. Secondly, the organizations employed the following KM processes: (1) creation, seeking knowledge, and knowledge capture; (2) storing, organizing, and maintaining knowledge; (3) diffusing, rendering knowledge, and knowledge sharing; and (4) giving feedback. However, Kianto et al. (2016) investigated the KMM and proposed five steps: (1) acquisition, (2) sharing, (3) creation, (4) encryption, and (5) knowledge retention. García-Fernández (2015) examined KM processes through the analysis of 78 research papers. Initially, knowledge creation was identified as acquiring information, disseminating information, and sharing knowledge. They then focused on knowledge storage and transfer aspects, such as applying knowledge in teamwork. Creating knowledge involves the ability to generate valuable ideas and approaches for an organization. This step is associated with different dimensions of operations within an organization, such as products, management practices, and technological procedures. Knowledge encryption encompasses activities to convert tacit knowledge into explicit knowledge, provide up-to-date knowledge to an organization's staff, and preserve formalized knowledge (Pham et al., 2020). The advantage of this process depends on the position and motivation of the workers, in addition to the technology infrastructure. Conserving knowledge is linked to human resource management's ability to reduce knowledge loss within an organization (2016).

Obeidat et al. (2016) conducted a study to investigate the effects of KM processes (acquisition, knowledge sharing, and knowledge usage) and KM methods (such as coding, social networks, and personalization) on the innovation of consulting firms in Jordan. The analysis indicated a significant and positive impact of KM processes on innovation in these firms. Social networks were found to have a significant and negative impact on innovation. Additionally, the study showed significant and positive impacts of personalization and methodology on innovation. Yusr et al. (2017) identified three factors of the KMM that enhance innovation: (1) acquiring knowledge, (2) disseminating knowledge, and (3) applying knowledge.

Furthermore, there have been several studies on KM in universities. Ahmadi and Ahmadi (2019) examined the KMM at Shushtar University, Iran, and their results suggested some KMM solutions to improve output and research processes. Studies indicate that factors in university KM processes include creating knowledge, gathering knowledge, applying knowledge, and disseminating knowledge (Matin & Kashani, 2012; Ghazali, 2007). Huang et al. (1998) proposed four processes for establishing a knowledge sharing and cooperation culture based on the KMM in universities: (1) making knowledge sensible, (2) increasing knowledge force, (3) establishing infrastructure for knowledge, and (4) building a motivating force for developing knowledge culture. From a scientific standpoint, the learning organization should begin at the individual level through partial knowledge creation, knowledge sharing among departments with similar academic interests or fields, and knowledge networks within

organizations or universities. The readiness of KM at the University of Bahrain was investigated by Al-Bastaki and Shajera (2012). Tsui et al. (2021) analyzed the KMM at Bangkok University. Islam et al. (2013) studied knowledge sharing among lecturers in two public universities in Bangladesh and found that knowledge sharing, along with other fundamental factors such as knowledge creation, collection, storage, and application, significantly impact the effectiveness of a university's academic research. Rivera and Rivera (2016) proposed a six-factor model as the KMM for higher education in Mexico, consisting of human resources, structure, culture, leadership, information technology, and measurement. These factors facilitate the creation, storage, transfer, and application of knowledge within universities. A survey consisting of 53 questions was designed for 36 individuals involved in managing knowledge implementation and development phases. The study indicated that human, cultural, and structural aspects play a prominent role in KMMs at universities. Do et al. (2020) confirmed that lecture performance is assessed by universities based on their role in teaching and research activities. The university serves as an encouragement for lecturers to engage in scientific activities. Naser et al. (2016) examined the KMM at Al-Azhar and Al-Quds universities in the Gaza Strip, Palestine, and the results indicated that leadership, process, people, and KM results influence the efficiency of academic research.

Meanwhile, Masa'deh et al. (2017) investigated the effect of KM on job performance at universities and found that KM has a negative impact on employee satisfaction, leading to decreased productivity. These results have sparked discussions among scholars regarding the application of KM in universities to enhance productivity through better academic research. Recently, lectures have been recognized as a vital factor in developing educational strategies and goals (Do & Canh, 2018; Do et al., 2020). In this study, 33 factors were initially identified through a literature review, and Table 1 presents these factors along with their corresponding references.

Table 1. Identification of KMM factors at universities via literature review

No.	Factor	References
1	Collecting knowledge	(Smith, 2001), (Miltiadis et al, 2003)
2	Capturing knowledge	(Castro et al, 2011), (Bigliardi et al, 2014) (Kianto et al, 2016), (Yusr et al, 2017)
3	Organizing knowledge	(Smith, 2001), (Bigliardi et al, 2014)
4	Distributing knowledge	(Smith, 2001), (Bigliardi et al, 2014)
5	Applying knowledge	(Smith, 2001), (Miltiadis et al, 2003), (Du Plessis, 2007), (Wigg 1993), (Garcia-fernandez, 2015), (Obeidat et al, 2016), (Yusr et al, 2017), (Islam et al, 2013), (Ahmadi et al, 2019)
6	Maintaining knowledge	(Smith, 2001), (Bigliardi et al, 2014), (Kianto et al, 2016)
7	Accumulating knowledge	(Smith, 2001)
8	Motivating employees	(Smith, 2001), (Lee et al, 2010), (Kianto et al, 2016)
9	Searching knowledge	(Bigliardi et al, 2014)
10	Transferring knowledge	(Miltiadis et al, 2003), (Bigliardi et al, 2014),
11	Information technology	(Lee et al, 2001), (Rivera, 2016)
12	Strategy	(Lee et al, 2001), (Do et al, 2018, 2020)
13	Leadership style	(Lee et al, 2001), (Rivera, 2016), (Naser et al, 2016)
14	Providing knowledge	(Wigg, 1993), (Huang et al, 2009)
15	Synthesize knowledge	(Wigg, 1993), (Huang et al, 2009)
16	Transform knowledge	(Du Plessis, 2007), (Huang et al, 2009), (Nonaka& Takeuchi, 1995), (Wigg 1993),
17	Reusing knowledge	(Wee &chua, 2013), (Garcia-fernandez, 2015)
18	Offering feedback	(Bigliardi et al, 2014)
19	Acquire knowledge	(Bigliardi et al, 2014)
20	Encrypt knowledge	(Kianto et al, 2016)
21	Making knowledge tangible	(Garcia-fernandez, 2015)
22	Enhancing knowledge intensity	(Garcia-fernandez, 2015), (Masadeh et al, 2017)
23	Building knowledge infrastructure	(Wee &chua, 2013)
24	Culture	(Lee et al, 20), (Rivera, 2016), (Naser et al, 2016)
25	Structure	(Kianto et al, 2016), (Rivera, 2016)
26	Human resources	(Wee &chua, 2013), (Rivera, 2016)
27	Knowledge measurement	(Wee &chua, 2013), (Rivera, 2016)
28	Knowledge processes	(Wee &chua, 2013)
29	Processes	(Garcia-fernandez, 2015), (Rivera, 2016), (Naser et al, 2016)
30	Knowledge assessment	(Garcia-fernandez, 2015)
31	Sharing knowledge	(Smith, 2001), (Castro et al, 2011), (Wee &chua, 2013) (Bigliardi et al, 2014), (Garcia-fernandez, 2015), (Kianto et al, 2016), (Obeidat et al, 2016)
32	Protecting knowledge	(Smith, 2001), (Miltiadis et al, 2003)
33	Creating knowledge	(Lee et al, 20), (Du Plessis, 2007), (Wigg 1993), (Castro et al, 2011), (Wee &chua, 2013), (Bigliardi et al, 2014), (Kianto et al, 2016), (Ahmadi et al, 2019)

3. Research methodology

In this study, a combination of literature and the Delphi method was used to extract the KMM factors from literature and expert judgment. Subsequently, the most influential factors of the KMM were identified to prioritize them as a predictive tool for modeling decision-makers' behaviors. Figure 1 illustrates the research methodology.

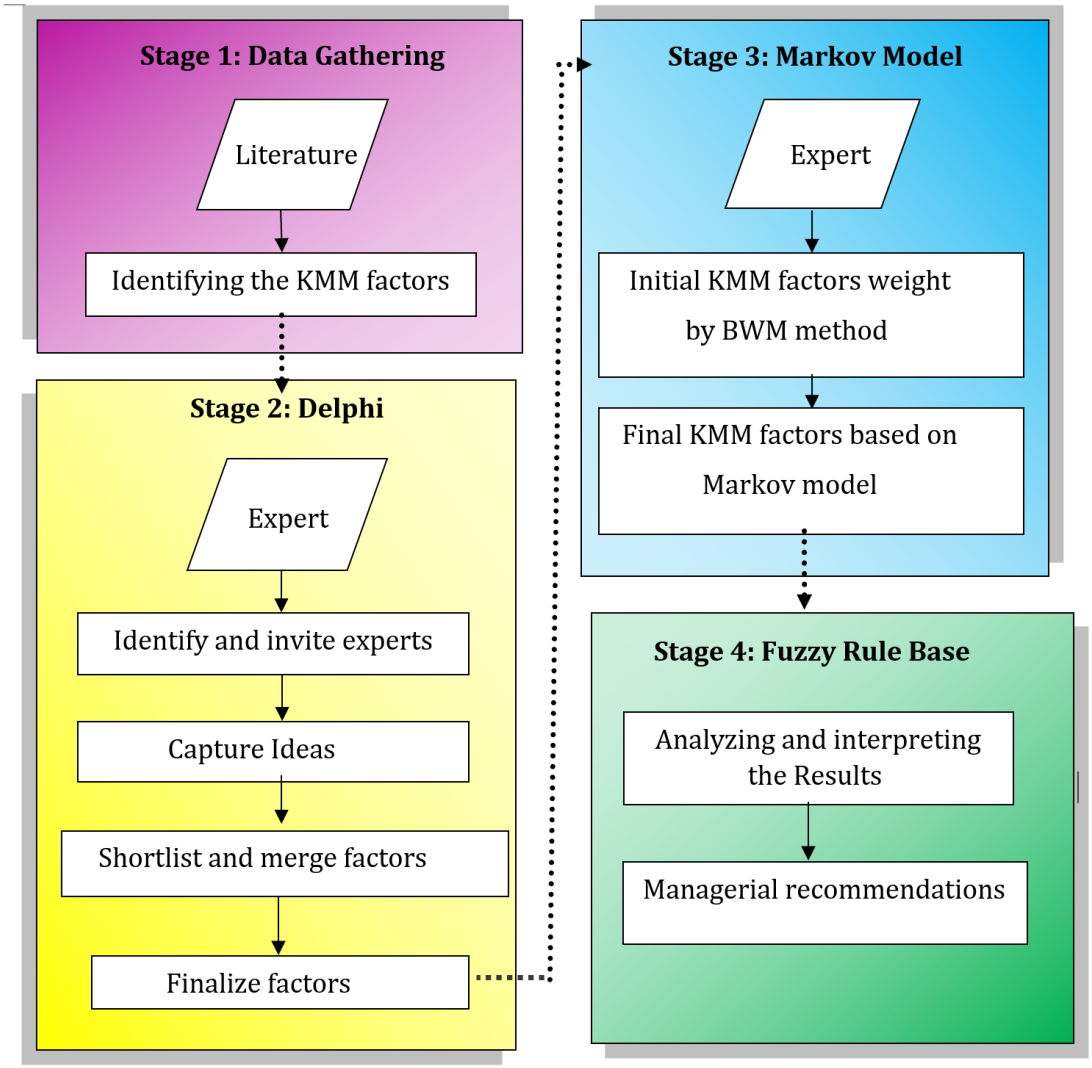

Figure 1. Research methodology

First, KMM factors in universities were extracted through a systematic literature review. These results contribute to the ongoing discussion among scientists regarding the enhancement of productivity and better academic research through the application of KM in universities. Initially, 33 factors were identified via the literature review. Subsequently, KM experts were engaged to merge and shortlist the features specifically for Iranian universities. The selection of factors by the experts was based on the characteristics of Iranian universities, their applicability and operationality, and their alignment with the culture of Iranian universities. The outputs of the Delphi method served as inputs for the best-worst method. The topics included in the model of KM at universities represent the most critical issues in KMM at universities. For the KMM sub-criteria, prioritization was conducted using the BWM to determine their importance in the output results as a weight vector. The Markov model was then employed to examine the long-term effects. The following sections present the methodology of the techniques employed in the proposed approach.

3.1 Delphi method

The Delphi method is employed to gather experts' opinions and reach a consensus (de Jesus et al., 2019). The Delphi method does not have a fixed approach; it can be adjusted based on the study and specific conditions (Gnatzy et al., 2011). According to Melander et al. (2019), there is no predetermined number of iterations for the Delphi method. However, to ensure sufficient expert participation, it is typically recommended to conduct the iterations in two or three phases (Shoukohyar & Seddigh, 2020).

3.2 BWM Method

BWM is used to rank and weigh criteria or factors. Unlike methods such as AHP, BWM does not require paired comparisons and it has higher consistency (Rezaei, 2015; Sazvar et al., 2022). In BWM, all criteria (factors) are compared with the best-worst criteria. The steps of BWM are presented in detail below:

Step 1: Experts define the decision-making factors. In this step, the problem and research objectives should be clarified.

Step 2: Experts determine the best and worst criteria.

Here, the most and least important criteria among the all are selected. Then, all other criteria (factors) are compared with the most and least important criteria. Experts determine the priorities of the best criterion over other criteria (BO) as numbers between 1 and 9. Also, Priorities of other criteria over the worst criterion (OW) are determined by experts as numbers between 1 and 9. The result from Best-to-Others comparisons is presented by vector $A_B = (a_{B1}, a_{B2}, \dots, a_{Bj}, \dots, a_{Bn})$ in which a_{Bj} demonstrates the decision makers' preference for criterion B over criterion j.

Step 3: Computing the weights of the criteria. The result from Others-to-Worst comparisons is presented by vector $A_w = (a_{1w}, a_{2w}, \dots, a_{jw}, \dots, a_{nw})$ in which a_{jw} demonstrates the decision makers' preference for criterion j over criterion W. The value of ideal weight $(w_1^*, w_2^*, \dots, w_n^*)$ is calculated for each criterion.

$$\begin{aligned} &\min \max_j \left\{ \left| \frac{w_B}{w_j} - a_{Bj} \right|, \left| \frac{w_j}{w_W} - a_{jW} \right| \right\} \\ &\sum_{j=1}^{n} w_j = 1 \\ &w_j \geq 0, \text{for all } j \end{aligned} \tag{1}$$

Equation (1) can also be written as equation (2):

$$\begin{aligned} &\min \xi \\ &s.t. \\ &\left| \frac{w_B}{w_j} - a_{Bj} \right| \leq \xi, \text{for all } j \\ &\left| \frac{w_j}{w_W} - a_{jW} \right| \leq \xi, \text{for all } j \\ &\sum_{j=1}^{n} w_j = 1 \\ &w_j \geq 0, \text{for all } j \end{aligned} \tag{2}$$

3. 3 Markov Model

It has been proven that the Markov model is efficient in finding solutions to problems (Liu, Chiu, & Chiu, 2011; Pourmoayed et al., 2016; Baumann & Sandmann, 2017). However, the usage of Markov models is relatively new (Asadabadi, 2016). This model has been applied in various contexts, such as analyzing market demand and supply by reducing the reliability of past data (Yu, Sheblé, & Matos,

2006), assessing the credit risk of bank loans (Lu, 2012), modeling multi-parameter processes for equipment designs (Berthiaux et al., 2004), comparing cost computing techniques (Farran & Zayed, 2009), predicting wind speed using historical data (Farran & Zayed, 2009), making rehabilitation policy decisions for infrastructure (Farran & Zayed, 2009), estimating customer lifetime values for an auto repair company in Taiwan (Cheng, 2012), and addressing issues in various other subjects. The Markov model considers different stages and the probabilities of transitioning from one stage to another in a matrix, allowing for long-term changes. The steps involved in using the Markov Model are outlined below:

- Identify different stages and their initial priorities: The list of stages with their normalized weights at time zero (the initial time) is obtained in the matrix W_{stages}.

$$W_{stages} = \begin{bmatrix} w_{s_1} \\ \vdots \\ w_{s_n} \end{bmatrix} \tag{3}$$

- Transition matrix

Markov model models dynamic changes within periods of time. Interval time can be defined as day, week, month, and year based on manager opinion. Set of states defined as different stages:

S= $\{s_1. s_2. \dots . s_n\}$. Also set of time considered is T= $\{t_0.t_1. \dots .t_m\}$. p_{ij} is the probability of moving from i^{th} state to j^{th} that changes from W_{si} to W_{sj}.

The one-step transition matrix is shown in the matrix P.

$$p = \begin{bmatrix} p_{11} & \cdots & p_{1n} \\ \vdots & \cdots & \vdots \\ p_{n1} & \cdots & p_{nn} \end{bmatrix} \tag{4}$$

For computing pij, we can use data from the past surveys or experts and managers opinion. Now, the matrix for changing probabilities between different stages after k period is calculated as in the matrix P_k. This matrix is in fact, multiplying matrix P, k times, consequently.

$$p^k = \begin{bmatrix} p_{11}^k & \cdots & p_{1n}^k \\ \vdots & \ddots & \vdots \\ p_{1n}^k & \cdots & p_{nn}^k \end{bmatrix} \tag{5}$$

- Calculating final weight

Now, by frequently multiplying matrix W_{stages} in transition matrix P^k

in different k, the weights of stages will change in k^{th} period after the initial time but after some periods, $w_{stages}^{(k)^T}$ converges to a unique matrix and no obvious deviation will occur. This matrix shows w_{stages}^*.

$$w_{stages}^{(k)^T} = w_{stages}^{(0)^T} p^{(k)} \tag{6}$$

4. Results

The literature review was conducted, and 33 features were extracted. KM experts were then consulted to identify and customize the features specifically for universities in Iran, resulting in nine final features. The outputs of the Delphi method were used as inputs for the best-worst method. The identified factors in KMM universities (Leadership style, Information technology, Culture, Collection of knowledge, Applying knowledge, Sharing knowledge, Maintaining knowledge, Structure, and Measurement) are crucial in the KMM at universities. Therefore, these nine factors were included in the survey. The BWM method was employed to prioritize the KMM factors and determine their weights in the output results. The Markov model was then used to consider long-term effects. It is important to note that relying solely on initial weights may lead to erroneous decisions, so the weights

of problem factors in subsequent periods should be taken into account. The Markov model's transition matrix is used to calculate the probabilities of prioritization changes and disruptions accurately. The following sections provide detailed explanations of each step.

4.1 Finalizing KMM factors through the Delphi method

In this step, a three-phased survey was conducted with the participation of 20 prominent experts. A questionnaire (provided in the Appendix) was designed, incorporating insights from the literature along with an open-ended question for suggesting other factors. To expedite the process, the survey questions were sent to the panelists, who were given three weeks to provide their responses. Table 2 presents the descriptions and outcomes of the three-phased Delphi survey (Shoukohya & Seddigh, 2021).

Table 2. Delphi method phases conducted by experts

	Phase 1	**Phase 2**	**Phase 3**
Description	Experts were provided with the data extracted from the literature (Table 1). They were asked to identify the most important factors KMMs at universities in Iran and shortlist the merging and overlapping characteristics.	The output of the first round were provided to the panel. The other merged factors proposed in the previous phase were also presented to the panel for assessment.	In this phase all the factors were presented to the panel for further assessment, modification and finalization.
Response Rate	20 out of 30	20 out of 20	20 out of 20
Outcome	The experts identified, merged and shortlisted the factors. Final outcome was nine factors which is presented in table below. Also, they merged the "applying knowledge" and "reusing knowledge", "maintaining", "protecting" and "preserving knowledge", "measurement" and "assessment", "accumulating knowledge" and "collecting knowledge".		

Experts involved in Delphi survey include KM consultants, university Professors of KM, KM practitioners at universities. Table 3 indicates the experts panel composition in three-phased Delphi survey.

Table 3. The experts panel composition

Experts panel	**Number of participants (first phase)**	**Number of participants (second and third phase)**	**Levels of expertise in KM (Year)**
KM consultants	10	7	>15
University Professors of KM	7	5	10-15
KM practitioners at universities	13	8	3-6

Finally, the factors of the KMM (F1-F9) extracted from literature review and Delphi method are presented in Figure 2.

4.2 Prioritization of KMM factors using Markov Model

In this stage, the best-worst method is employed to determine the initial weights of the KMM factors. It is important to highlight that in the event of conflicting opinions, experts engage in discussions until a consensus is reached (Azadeh et al., 2017). This approach allows experts to provide an optimistic viewpoint, a pessimistic viewpoint, or a viewpoint that falls in between. Figure 3 visually represents the weights of the KMM factors.

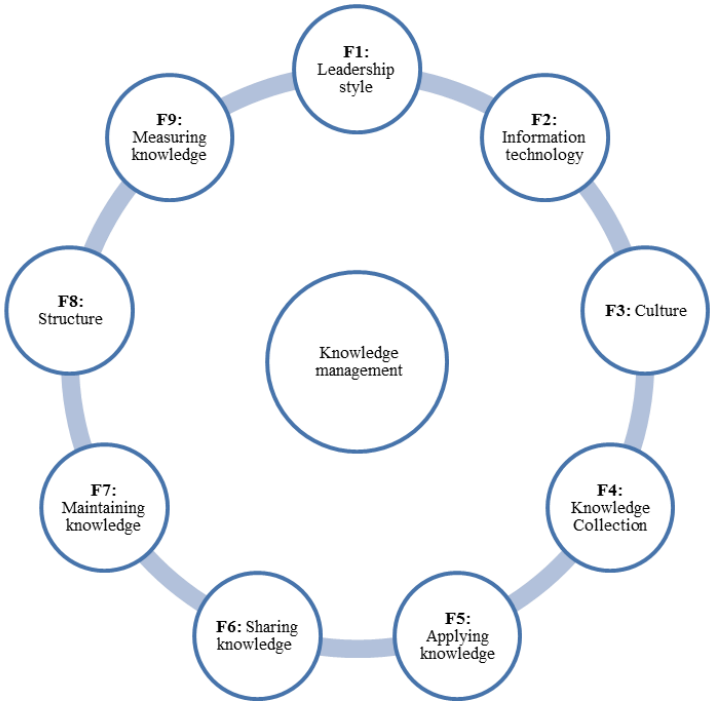

Figure 2. Research model

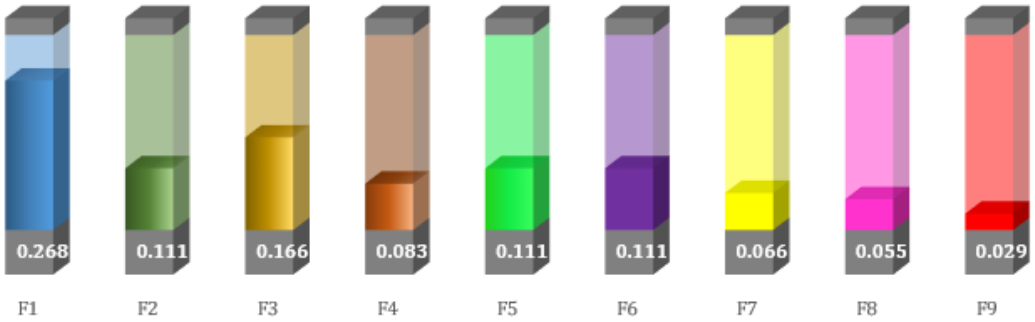

Figure 3. Factors weights based on BWM

Bases on the results, F1 (Leadership style) is the best and F9 (Measuring knowledge) is the worst factor. Also, consistency index (0.064) indicates the consistency among the comparisons. The initial list of KMM factors at time zero is presented in the matrix W_{KMM}.

$$W_{KMM} = \begin{matrix} F1 \\ F2 \\ F3 \\ F4 \\ F5 \\ F6 \\ F7 \\ F8 \\ F9 \end{matrix} \begin{bmatrix} 0.268 \\ 0.111 \\ 0.166 \\ 0.083 \\ 0.111 \\ 0.111 \\ 0.066 \\ 0.055 \\ 0.029 \end{bmatrix}$$

Then, because of uncertainty and changes, these weights may not be fixed during the time passing due to changes in factors' importance in various situations. So, the Markov model considers dynamic changes over a special time horizon. The one-step transition matrix of KMM factors is shown in matrix A. These probabilities are extracted from an expert group based on recent reports and their predictions. Where:

p_{ij}: the probability of moving from the prioritization of i^{th} factor to j^{th} one

$$A = \begin{array}{c} Factors \\ F1 \\ F2 \\ F3 \\ F4 \\ F5 \\ F6 \\ F7 \\ F8 \\ F9 \end{array} \begin{bmatrix} F1 & F2 & F3 & F4 & F5 & F6 & F7 & F8 & F9 \\ 0.1 & 0.17 & 0.13 & 0.10 & 0.21 & 0.10 & 0.05 & 0.08 & 0.06 \\ 0.15 & 0.10 & 0.09 & 0.11 & 0.19 & 0.12 & 0.09 & 0.08 & 0.07 \\ 0.08 & 0.15 & 0.08 & 0.09 & 0.21 & 0.15 & 0.11 & 0.05 & 0.08 \\ 0.0.6 & 0.11 & 0.08 & 0.16 & 0.07 & 0.13 & 0.13 & 0.14 & 0.12 \\ 0.23 & 0.12 & 0.17 & 0.10 & 0.11 & 0.09 & 0.06 & 0.07 & 0.05 \\ 0.19 & 0.12 & 0.15 & 0.14 & 0.12 & 0.05 & 0.14 & 0.04 & 0.05 \\ 0.04 & 0.14 & 0.10 & 0.12 & 0.08 & 0.11 & 0.13 & 0.14 & 0.14 \\ 0.03 & 0.16 & 0.09 & 0.03 & 0.06 & 0.10 & 0.12 & 0.22 & 0.19 \\ 0.02 & 0.13 & 0.08 & 0.04 & 0.03 & 0.09 & 0.09 & 0.240 & 0.28 \end{bmatrix}$$

Now, the matrix for transforming probabilities between different stages after k period is computed as in the matrix A^k. Consequently, this matrix is multiplied by matrix A, k times.

Transition between states at k^{th} period is indicated in Figure 4.

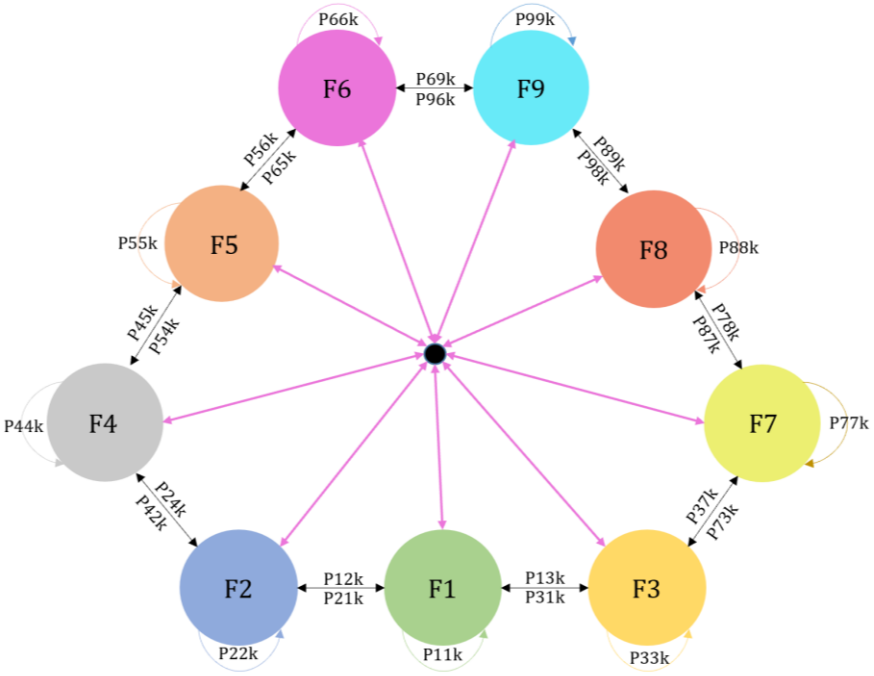

Figure 4. Transition between KMM factors at k^{th} period

Now, by multiplying matrix W_{KMM} in transition matrix A^k in different k, the weights of factors will be computed in k^{th} period after the initial time.

$$W_{KMM}{}^{(k)^T} = W_{KMM}{}^{(0)^T} A^{(k)}$$

Within several periods, $W_{KMM}{}^{(k)^T}$ numbers convergences to same matrix showing W^*_{KMM}.

$$W_{KMM}{}^{(0)^T} = W_{KMM}{}^{(0)^T} A^{(0)} = [0.113 \quad 0.139 \quad 0.114 \quad 0.105 \quad 0.153 \quad 0.107 \quad 0.092 \quad 0.091 \quad 0.086]$$

$$W_{KMM}{}^{(1)^T} = W_{KMM}{}^{(0)^T} A^{(1)} = [0.111 \quad 0.132 \quad 0.111 \quad 0.101 \quad 0.127 \quad 0.105 \quad 0.099 \quad 0.109 \quad 0.106]$$

$$W_{KMM}{}^{(2)^T} = W_{KMM}{}^{(0)^T} A^{(2)} = [0.104 \quad 0.133 \quad 0.109 \quad 0.099 \quad 0.123 \quad 0.105 \quad 0.101 \quad 0.115 \quad 0.13]$$

$$W_{KMM}{}^{(3)^T} = W_{KMM}{}^{(0)^T} A^{(3)} = [0.103 \quad 0.133 \quad 0.108 \quad 0.0.98 \quad 0.121 \quad 0.105 \quad 0.101 \quad 0.117 \quad 0.115] \quad i \geq 3$$

In addition, in spite of initial priority, final KMM factors weights based on Markov model is presented in Figure 5.

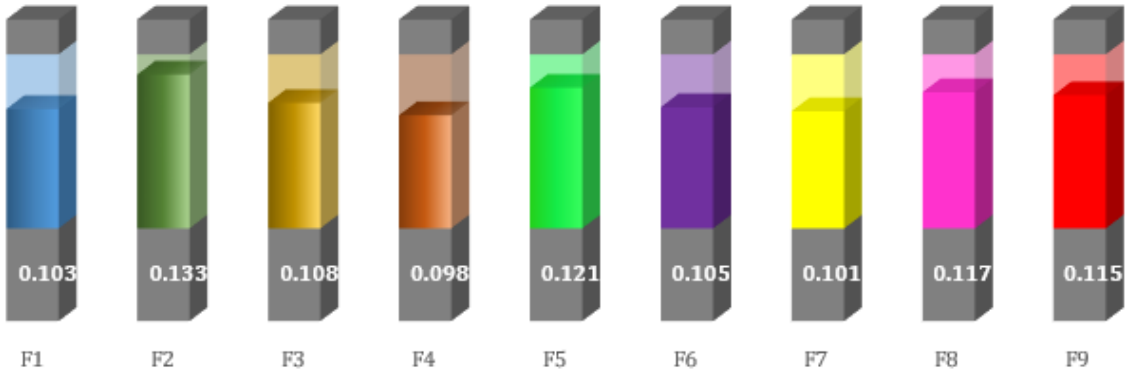

Figure 5. The final KMM factors weights based on Markov model

In the Figure 6, we have compared the initial and secondary KMM factors weights based on BWM and Markov.

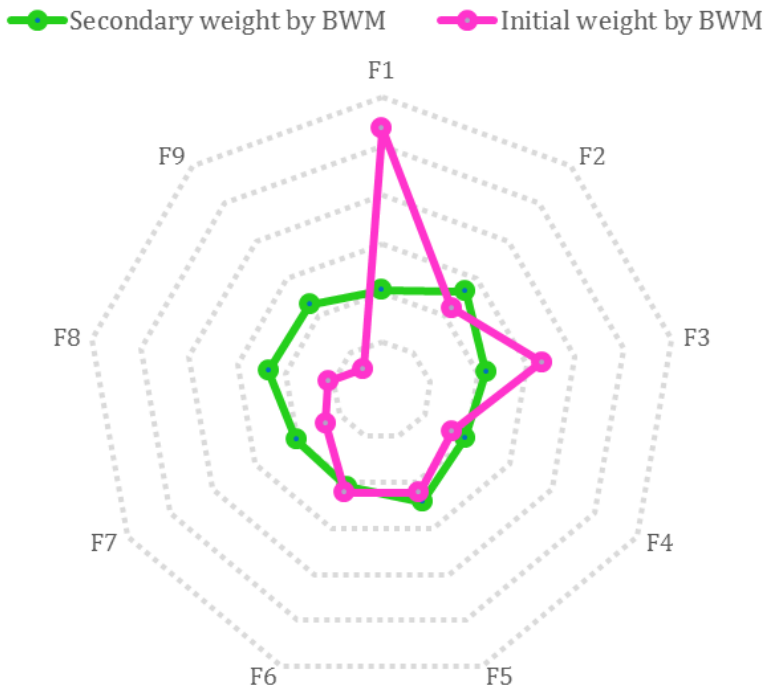

Figure 6. Comparing initial and secondary KMM factors weight

Figure 6 presents a comparison of the weights of the KMM factors in the KMM at universities in Tehran, Iran, using the BWM and Markov methods.

In Figure 4, which displays the BWM weights, Leadership style (0.268) is ranked first, followed by Culture (0.166) in second place. Information technology, Application of knowledge, and sharing knowledge (0.111) share the third rank. Collecting knowledge (0.083), Maintaining knowledge (0.066), and structure (0.055) occupy the fourth, fifth, and sixth ranks, respectively. Measuring knowledge (0.029) receives the lowest rank based on the BWM results. After deriving the factor weights using the BWM method, the ranking of factors based on the Markov method is presented in Figure 6. The results depicted in Figure 6 indicate the experts' perception and knowledge regarding the similar priority and importance of all the selected factors in the KM research model. Minor differences are observed in the results obtained through the Markov method. Information technology obtains the highest value and ranks first (0.133), followed by applying knowledge in the second position (0.121). Structure (0.117), measuring knowledge (0.115), and culture (0.108) secure the third, fourth, and fifth ranks, respectively. Sharing knowledge (0.105), leadership style (0.103), maintaining knowledge (0.101), and collecting knowledge (0.098) occupy the sixth, seventh, eighth, and ninth positions,

respectively. Consistency in the importance of factors is achieved after two years of experience in knowledge management.

5. Conclusions

This study aimed to explore and evaluate the factors of KMM at universities in Tehran, Iran. The authors provided an overview of the current KMM and the KMM at universities. Initially, a literature review was conducted, including articles, papers, books, and technical sites. A total of 33 KMM factors were identified through the literature review. These factors were then reviewed and merged by experts, resulting in nine factors through expert consensus.

The Best-Worst Method (BWM) was used to determine the weights of the factors in the first stage. Additionally, the Markov method was utilized to trace the priorities of KMM factors, which serve as a predictive tool for modeling KM factors. The Markov method provides a Markovian weighted average of KMM factors as an optimal solution with the lowest error.

Through the literature review and Delphi method, the KMM factors specific to universities in Tehran, Iran were customized by experts. The BWM method was employed to evaluate and weigh these KMM factors.

The findings from the BWM method revealed the analysis and ranking of the nine factors. The rankings obtained through BWM are as follows: Leadership style, with the highest weight, was ranked first, while Measuring knowledge, with the least weight, was ranked as the worst factor. To trace the priorities of KMM factors, the Markov model was used as a predictive tool. The Markov model's probabilities are particularly useful when decision-makers and experts have limited experience, which is applicable in Iranian universities. These priorities changed from the initial KMM priorities. The Markov model simplifies the identification of patterns for KMM factors, allowing decision-makers to adjust their preferences and focus on different factors. By tracing frequent changes, the Markov model identifies patterns of KMM factors that can be used instead of the initial weights obtained for KMM. This means that decision-makers can adapt their preferences and give careful consideration to specific factors within the overall system.

Consistency among the importance of factors was achieved after two years of knowledge management experience. The rankings of the Markov model are as follows: Information technology ranks first with the highest value, followed by applying knowledge in second place. Structure, measuring knowledge, and culture are ranked third, fourth, and fifth, respectively. Finally, sharing knowledge, leadership style, maintaining knowledge, and collecting knowledge are ranked sixth, seventh, eighth, and ninth, respectively.

To compare the findings with previous research and methods, unique features of this study and specific criteria are defined, compared, and presented in the table 4.

Clearly, based on the consistency of the weights in the Markov method results, it can be concluded that decision-makers should, to some extent, invest and utilize all factors equally. The highest priority given to information technology indicates that managers and decision-makers should invest in KM technical software and platforms, ensuring a high-quality and standardized infrastructure.

The importance of applying knowledge highlights that universities, similar to other organizations in Iran, are not fully aware of the usability and reusability of knowledge. On the other hand, the lower priority assigned to collecting knowledge confirms that universities tend to focus more on accumulating and collecting knowledge rather than actively applying, utilizing, and reusing it. This can be attributed to the implementation of KM in our universities, which often becomes a mere display, as observed in many governmental organizations.

In reality, due to the requirements of standards and guidelines for KM implementation in Iranian organizations, there is a rush to adopt KM platforms and techniques. As a result, a large amount of knowledge is accumulated through methods like interviews without actually being utilized. To address this issue, it is recommended to prioritize problem-based KM approaches and emphasize the application and use of stored knowledge in educational matters and updating guidelines as fundamental principles.

Table 4 Comparing current study with the previous research findings and methods

features \ Studies	Current study	Ahmadi (2019)	Rivera (2016)	Naser et al (2016)	Ghezzi & Cavallo, (2020)	Shujahat et al (2019)	Bigliardi et al (2014)	Mas'deh et al (2017)
mixed method of qualitative- quantitative	✓							
Identifying factors based on literature review	✓	✓		✓	✓			✓
Customizing and merging factors based on expert interview	✓							
Using integrated Machine Learning- approach	✓							
Determining initial and secondary weights	✓							
predicting behaviors of KMM factors	✓							
Factors identified, merged and customized	(1) Information Technology; (2) applying; (3) structure; (4) Measuring (5) culture; (6) Sharing (7) leadership style; (8) Maintaining and (9) Collecting	(1) Creating, (2) gathering, (3) applying, and disseminating	(1) creation, seeking, and knowledge capture; (2) storing, organizing, and maintaining; (3) diffusing, rendering, and sharing; and (4) giving feedback	(1) acquisition, (2) sharing, (3) creation, (4) encryption, and (5) knowledge retaining	(1) human resources; (2) Structure; (3) culture; (4) leadership; (5) information technology; and (6) measurement	(1) creation, (2) sharing, and (3) knowledge reuse	(1) accumulating; (2) transferring; (3) using; and (4) preserving knowledge	(1) making knowledge sensible; (2) increasing knowledge force; (3) making infrastructure; and (4) building a motivating force
Factors Priorities	Information technology ranks first with the highest value. Applying knowledge placed second. Structure, measuring knowledge, and culture are ranked third, fourth and fifth, respectively. Finally, the sixth, seventh, eighth, and ninth rank belonged to Sharing knowledge, leadership style, maintaining knowledge, and Collecting knowledge, respectively.	No Ranking	The study indicated that human, cultural, and structural aspects are prominent in KMMs at universities	Results indicated that the leadership, process, people, and KM results affect the efficiency of academic research.	No Ranking	the results signify the overarching role of the human and cultural approach to knowledge management over the Big Data and IT and system-based approaches	No Ranking	These results show a discussion among scientists that when applying KM, universities will enhance productivity through better academic research.

In terms of practical implications regarding KMM factors, it should be acknowledged that universities, like other organizations, face challenges in identifying optimal, customized, and effective KMM factors. In this study, we identified nine factors through literature review and expert input. These factors include (1) Leadership style, (2) Information technology, (3) Culture, (4) Collection of knowledge, (5) Applying knowledge, (6) Sharing knowledge, (7) Maintaining knowledge, (8) Structure, and (9) Measurement. All of these elements are crucial components of KMM that should be taken into consideration by university managers and decision-makers.

Among the identified factors, we initially determined their weights and priorities in the KMM. Based on the initial weights, we observed that leadership style ranked first, followed by culture in the second position. Information technology, application of knowledge, and sharing knowledge were tied for the third rank. Collecting knowledge, maintaining knowledge, and structure obtained the fourth, fifth, and sixth ranks respectively. Measuring knowledge ranked last.

To enhance the performance of KM implementation at universities and predict future KMM factors, we employed an integrated Machine Learning-Markov approach known as Markov. The

results obtained from the new Markov model revealed that universities often focus on ineffective factors in an incorrect and suboptimal manner. The final results indicated that Information technology ranked first with the highest value, followed by applying knowledge in the second position. Structure, measuring knowledge, and culture were ranked third, fourth, and fifth respectively. Finally, sharing knowledge, leadership style, maintaining knowledge, and collecting knowledge occupied the sixth, seventh, eighth, and ninth ranks respectively.

These findings highlight the significance of Information technology, applying knowledge, structure, and measuring knowledge as the most influential factors after two years. Additionally, culture is assessed as a high priority, emphasizing the essential role of university members in improving the culture of knowledge, science, technology, and innovation. In the current context, the importance of factors such as collecting knowledge and maintaining knowledge is relatively diminished since universities in Iran primarily accumulate and maintain knowledge without significant utilization. These results also shed light on the specific objectives of most universities in Iran. It is recommended that universities prioritize key aspects of knowledge governance, including IT, structure, culture, and knowledge sharing. Such an approach aligns with the implementation approaches and priorities of knowledge in Iran.

In other words, managers and decision-makers in Iranian universities, particularly those in Tehran, should prioritize the essential factors and elements such as information technology, knowledge application, and structure. The implementation of techniques that impact these high-priority factors is crucial for enhancing KM practices. It is important for universities to allocate their budget and resources optimally in order to improve KM. Many Iranian organizations tend to prioritize measuring knowledge due to standard requirements, without taking specific actions to implement KM effectively.

Another key point that can be inferred from this study is the significance of leadership support for KM. Leaders should emphasize the use of knowledge application and information technology tools and techniques as essential components of KM. These findings have important implications for KMM in Iranian universities, where leadership and motivation for scientific research may not be prioritized adequately. They also provide valuable insights for future studies investigating KM-related issues in Iranian universities.

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Appendix

Questionnaire

I am Ph.D. student in Shahid Beheshti University working on "KNOWLEDGE MANAGEMENT Models" at universities. I request you to please answer the open-ended questions.

In this study, we aim to collect, make, and combine a comprehensive and systematic review of KM and KMMs at universities. We attempt to confirm the important factors in the KMMs used at universities in Iran.

Introduction: researches indicate that knowledge Management and it's fundamental factors significantly impact a university's academic research effectiveness. This project is to find the KM Factors and KM models at universities in Tehran, Iran.

Initially, 33 factors were identified via literature review, and table below demonstrates these 33 factors along with their references.

No.	Factor	References
1	Collecting knowledge	(Smith, 2001), (Miltiadis et al, 2003)
2	Capturing knowledge	(Castro et al, 2011), (Bigliardi et al, 2014) (Kianto et al, 2016), (Yusr et al, 2017)
3	Organizing knowledge	(Smith, 2001), (Bigliardi et al, 2014)
4	Distributing knowledge	(Smith, 2001), (Bigliardi et al, 2014)
5	Applying knowledge	(Smith, 2001), (Miltiadis et al, 2003), (Du Plessis, 2007), (Wigg 1993), (Garcia-fernandez, 2015), (Obeidat et al, 2016), (Yusr et al, 2017), (Islam et al, 2013), (Ahmadi et al, 2019)
6	Maintaining knowledge	(Smith, 2001), (Bigliardi et al, 2014), (Kianto et al, 2016)
7	Accumulating knowledge	(Smith, 2001)
8	Motivating employees	(Smith, 2001), (Lee et al, 2010), (Kianto et al, 2016)
90	Searching knowledge	(Bigliardi et al, 2014)
10	Transferring knowledge	(Miltiadis et al, 2003), (Bigliardi et al, 2014),
11	Information technology	(Lee et al, 2001), (Rivera, 2016)
12	Strategy	(Lee et al, 2001), (Do et al, 2018, 2020)
13	Leadership style	(Lee et al, 2001), (Rivera, 2016), (Naser et al, 2016)
14	Providing knowledge	(Wigg, 1993), (Huang et al, 2009)
15	Synthesize knowledge	(Wigg, 1993), (Huang et al, 2009)
16	Transform knowledge	(Du Plessis, 2007), (Huang et al, 2009), (Nonaka& Takeuchi, 1995), (Wigg 1993),
17	Reusing knowledge	(Wee &chua, 2013), (Garcia-fernandez, 2015)
18	Offering feedback	(Bigliardi et al, 2014)
19	Acquire knowledge	(Bigliardi et al, 2014)
20	Encrypt knowledge	(Kianto et al, 2016)
21	Making knowledge tangible	(Garcia-fernandez, 2015)
22	Enhancing knowledge intensity	(Garcia-fernandez, 2015), (Masadeh et al, 2017)
23	Building knowledge infrastructure	(Wee &chua, 2013)
24	Culture	(Lee et al, 20), (Rivera, 2016), (Naser et al, 2016)
25	Structure	(Kianto et al, 2016), (Rivera, 2016)
26	Human resources	(Wee &chua, 2013), (Rivera, 2016)
27	Knowledge measurement	(Wee &chua, 2013), (Rivera, 2016)
28	Knowledge processes	(Wee &chua, 2013)
29	Processes	(Garcia-fernandez, 2015), (Rivera, 2016), (Naser et al, 2016)
30	Knowledge assessment	(Garcia-fernandez, 2015)
31	Sharing knowledge	(Smith, 2001), (Castro et al, 2011), (Wee &chua, 2013) (Bigliardi et al, 2014), (Garcia-fernandez, 2015), (Kianto et al, 2016), (Obeidat et al, 2016)
32	Protecting knowledge	(Smith, 2001), (Miltiadis et al, 2003)
33	Creating knowledge	(Lee et al, 20), (Du Plessis, 2007), (Wigg 1993), (Castro et al, 2011), (Wee &chua, 2013), (Bigliardi et al, 2014), (Kianto et al, 2016), (Ahmadi et al, 2019)

Please, merge and shortlist the features based on the characteristics of Iranian universities, applicability, operationality and in accordance with the culture of Iranian universities.

Draw a circle around the desired factors and if you need to merge several items or suggest a new name, write it down in the section below.

If you have other factors than the ones suggested above, please let us know in the section below.