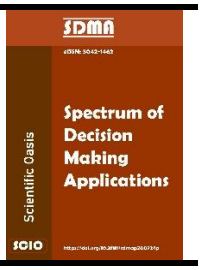
SCIENTIFIC OASIS

Spectrum of Decision Making and Applications

Journal homepage: www.dmap-journal.org
ISSN: 3042-1462



E-Procurement Readiness Assessment in Hospitals: A Novel Hybrid Fuzzy Decision Map and Grey Relational Analysis Approach

Mohammad Reza Rouhani Tazangi[1, *], Benyamin Feghhi[1], Dragan Pamucar[2,3,4,*]

[1] Department of Industrial Engineering, Fouman Faculty of Engineering, University of Tehran, Tehran, Iran
[2] Department of Applied Mathematical Science, College of Science and Technology, Korea University, Sejong 30019, Republic of Korea
[3] Industrial Engineering Department, Faculty of Engineering and Natural Sciences, İstinye University, İstanbul, Türkiye
[4] School of Engineering and Technology, Sunway University, Selangor, Malaysia

ARTICLE INFO

Article history:
Received 21 August 2024
Received in revised form 17 December 2024
Accepted 24 February 2025
Available online 4 March 2025

Keywords:
E-Procurement; E-Readiness; Hospital; Grey Relational Analysis; Fuzzy Decision Map; Critical success factors

ABSTRACT

E-procurement systems provide many opportunities to improve supply and procurement activities in the healthcare sector. However, their implementation has failed in several cases. Accordingly, adequate preparation is quite necessary at the pre-implementation stage. In this research, a holistic framework has been developed to evaluate e-procurement readiness in hospitals. Critical success factors in the implementation of e-procurement systems are explored based on the literature and experts' opinions. Twenty-six critical success factors have been identified and categorized across five dimensions: management, technology, process, human resources, and environment. Also, the most influential factors affecting hospital readiness for the successful implementation of the e-procurement system are characterized. The most important factors are identified using Grey Relational Analysis (GRA). The cause-and-effect relationships and the interplay among the factors are investigated by adopting a Fuzzy Decision Map (FDM) approach. To evaluate the proposed framework in practice, it is applied to a case study of a specialty hospital located in Tehran, Iran. This research, along with the development of readiness assessment literature in terms of theory and methodology, provides a valid tool to be applied during the pre-preparation stage of e-procurement systems.

1. Introduction

The healthcare industry is one of the largest with extremely high investments (Mathews *et al*., [1]). One of the reasons for increasing costs in healthcare systems is the inefficiency of supply chain operations. Supply and procurement are among of the major sectors in the healthcare industry – particularly hospital systems – and implementation of e-procurement systems can bring significant benefits such as reducing costs, increasing the speed as well as better responding to the service recipients (Saha *et al*., [2]).

[*] *Corresponding author.*
E-mail address: rezarohani92@gmail.com; dpamucar@gmail.com

https://doi.org/10.31181/sdmap21202523

E-procurement refers to the use of electronic communication based on the Internet for transactions between buyers and sellers in business processes. The benefits of using e-procurement systems in the healthcare and hospital systems are easy access to market information, on time reports, better management and control of suppliers, cost reduction in the overall purchase process, integrated information sharing, etc. (Adjei *et al*., [3]; Bahaddad *et al*., [4]). Despite the many advantages of these systems, their implementation results in failure in many cases. The cost of failure is significant due to the high investment and major changes in processes. Hence, the successful implementation of electronic systems requires the development of adequate readiness in different areas related to system performance (Balasubramanian *et al*., [5]). Consequently, evaluating readiness prior to the implementation of the e-procurement system is quite necessary.

Based on our best knowledge from existing literature, there is no comprehensive framework for e-procurement readiness assessment, especially in the healthcare systems and hospitals. Due to the challenges and obstacles to the implementation of the system, they need to be evaluated and also a comprehensive framework for readiness assessment of the system needs to be developed. The aim of this paper is to develop a novel framework for the assessment of hospitals' readiness to implement e-procurement systems, and the analysis of the relationships between readiness criteria to identify the most influential factors in readiness of hospitals for successful implementation of the system. To do so, a new hybrid approach using Gray Relational Analysis (GRA) and Fuzzy Decision Map (FDM) is proposed.

GRA methods provide decision makers with several advantages over regression models. In contrast to statistical and probability theory models, GRA models do not require large samples or typical probability distributions. Many fields have successfully applied GRA models, when it comes to healthcare-related studies, GRA models has been applied to healthcare service (Hsni *et al*.,[6]), efficiency (Liu *et al*., [7]), patient satisfaction (Peng *et al*., [8]; Javed *et al*., [9]), etc. GRA is used to determine the set of readiness factors with a higher degree of importance and ignore those with low importance, and also to assess the level of readiness. Then, FDM is applied to analyze cause and effect relationships and identify the degree of influence, as well as the inter-relationships among the factors.

The framework is implemented in a case study of a specialized hospital located in Tehran, Iran to determine the main areas for improving readiness and implement the e-procurement system. The result of this assessment determines the current state of the hospital's readiness to implement the system. Furthermore, it identifies the areas which need to be improved prior to the implementation stage.

The remainder of the paper is organized as follows. In Section 2, the literature review is presented, including the identified critical success factors for the implementation of e-procurement systems and e-readiness models. In Section 3, an integrated conceptual framework for assessing the readiness of hospitals is presented. Then, Section 4 discusses the role of GRA and FCM method in the current research structure. In Section 5, a case study and the obtained results regarding the most influential and important factors in hospital readiness as well as the results of readiness assessment for the case hospital are presented. Finally, in Section 6, a summary of the results and the conclusions of the study are provided.

1.1 Literature Review

1.1.1 E-procurement readiness assessment

By investigating the literature, it is concluded that although various studies on implementation of e-procurement system have been conducted in the healthcare sector, less consideration in the subject of assessment of readiness for this system has been taken into account. There is no prior

research focusing on the e-procurement readiness in hospitals and health centers and no comprehensive, practical model for evaluating the readiness for the system. Due to the importance of healthcare domain, conducting research on evaluation of the readiness for e-procurement system in hospitals is necessary to fill the mentioned gaps. To extend the proposed model in this paper, the key factors in success in the e-procurement system, as well as the models evaluating, the e-readiness should be known. Hence, the literature of these two cases is examined in the remainder of the article.

1.1.2 Critical success factors in e-procurement implementation

Critical success factors are in fact the key areas for which satisfactory results will ensure good performance of the system (Sangari *et al*., [10]). Several studies have been done regarding critical success factors in e-procurement implementation each focusing on identifying one or more of these factors. Adjei-Bamfo *et al*., [11] examines Ghana's public sector and highlights the importance of assessing readiness for full e-procurement adoption in lower and lower-middle income countries (LMICs), identifying institutional, economic, and socio-technical determinants as critical drivers beyond basic technological infrastructure. Drawing on elite interviews and a holistic framework informed by institutional theory and the UN E-Government Development Index, the study emphasizes process-oriented management as essential for success in complex environments. Similarly, Barajei *et al*., [12] investigates e-procurement's anti-corruption potential in Ghanaian mining firms, identifying breaking the monopoly of power, transparency and accountability, and reducing information asymmetry as key factors that mitigate procurement fraud and corruption, with the former being the most effective based on factor analysis of practitioner perspectives. Additionally, Althabatah *et al*., [13] proposes a fuzzy-rule-based model to assess procurement maturity in the context of Procurement 4.0, emphasizing modularity, resilience, agility, and human-centricity as vital components for enabling innovative procurement operations, particularly in the energy sector, with validation through a case study demonstrating its utility in optimizing strategies amid uncertainty. As seen in Table 1, the summary of organizational infrastructure and technological factors have been identified in the literature.

Table 1
Critical success factors for e-procurement implementation

CSF	References	CSF	References
E-procurement system integration with existing IT systems	Vaidya *et al.* [14]	Supplier management	Angeles and Nath [15]
Process reengineering	Leipold *et al*., [16]	Appropriate IT infrastructure	Tutu *et al*., [17]
Change management	Yusif *et al*., [18]	Manager's expertise in the field of ICT	Nguyen *et al*., [19]
Compliance with regulations and policies	Altayyar *et al*., [20]	Organizational Culture	Nguyen *et al*., [19]
Employee training	Brandon and Kauppi [21]	Supplier readiness	Panayiotou *et al*. [22]
Appropriate security systems	Vaidya *et al*., [14]	Organizational Leadership	Gunasekaran *et al*., [23]
Support and commitment of senior management	Afolabi et al., [24]; Wimalasena & Gunatilake [25]	Employee skills	Ali and Abbas [26]
Performance measurement and continuum monitoring system performance	Vaidya *et al*., [14]	Government support	Altayyar *et al*., [20]
Support and financial management	Gunasekaran *et al*., [23]	Employee Acceptance	Altayyar *et al*., [20]

1.1.3 E-readiness models

In the information era, studying about e-readiness for the purpose of developing the necessary capabilities in technical and organizational aspects is becoming increasingly important (Fathian *et al*., [27]). The most important tools in the framework of the readiness of the e-procurement system that can be used in hospitals as well as the evaluation indices are given in Table 2.

Table 2
Common e-readiness assessment models

Model	Dimensions	References
Center for International Development (CID)	E-access, E-learning, E-society, E-economy, E-policy	Chipembele and Bwalya [28]
Economist Intelligence Unit (EIU)	Connectivity (30%), Business Environment (20%), E-Commerce Consumer and Business Adoption (20%), Legal and regulatory Environment (15%), Supporting e-Services (10%), Social and cultural Infrastructure (5%)	Chipembele and Bwalya [28]
VERDICT	Management, Human Resources, Technology, process	Ruikar et al., [29]
Mutula & van Brakel	Enterprise e-readiness, Human resources readiness, Information readiness, ICT readiness, External environment readiness	Mutula and Van Brakel [30]
KPMG	E-strategy, project management, risk management, value chain management, performance management	Memarzadeh and Jahany [31]
P3I3	IT readiness, information technology, human resources, IT infrastructure	Memarzadeh and Jahany [31]

1.1.4 Grey Relational Analysis (GRA) models and Fuzzy Decision Map (FDM)

In this research, a practical framework using Grey Relational Analysis (GRA) and Fuzzy Decision Map (FDM) is developed to determine the level of a hospital's readiness to implement an e-procurement system. The grey system theory was first proposed by J. Deng in 1982. Despite a limited number of variables and poor information, it can still calculate the underlying relationship (Sun *et al*., [32]). By using gray relational analysis (GRA), new and convenient approaches can be applied to parse systems from which adequate or inadequate sample sizes were obtained that do not require classical distribution standards, and provide accurate results despite discrepancies between quantitative and qualitative findings. Based on Javed *et al*., [33] study, with small samples of data, gray relational analysis exhibits high precision. In the last few decades, gray relational analysis has evolved into several concepts. In environmental engineering, Arici *et al*., [34] applied Taguchi-based GRA to optimize a pond aeration system, balancing multiple objectives such as energy efficiency and oxygen transfer. Similarly, in manufacturing, Lee and Chen [35] combined the Taguchi method with GRA to enhance photo polymerization performance, improving process reliability under uncertainty. Additionally, in automotive engineering, Elumalai *et al*., [36] used GRA to optimize engine parameters for an ammonia biodiesel dual-fuel engine, maximizing output characteristics like power and emissions efficiency. Another contribution of this paper is to identify the most influential and important factors in the implementation of the system in hospitals. The benefits of the proposed framework are illustrated by results obtained from a real case study. Also, in this paper, the strengths and weaknesses of the case hospital with regards to the system implementation are identified.

2. Conceptual framework for evaluating the readiness of the e-procurement system in hospitals

In order to develop the comprehensive conceptual framework for evaluating the readiness in hospitals and implementation of the e-procurement system, a comprehensive research on models, the e-readiness frameworks and their dimensions as well as the domain of their application has been

conducted, Figure 1. Therefore, the models that can potentially be used as the primary framework for assessing the system readiness are identified. After that, E-procurement critical success factors are adapted to readiness dimensions in selected models, and the final dimensions are identified along with assessment criteria. Furthermore, in order to verify the validity of analyses, dimensions, and criteria, 13 academic specialists, IT consultants, procurement consultants in healthcare systems were interviewed and their opinions were applied to the conceptual framework development. These people have at least ten years of working experience in procurement, logistics, ICT, and hospital systems. To design and expand the system readiness framework in hospitals, open interviews were conducted to reach a consensus among experts during numerous interviews.

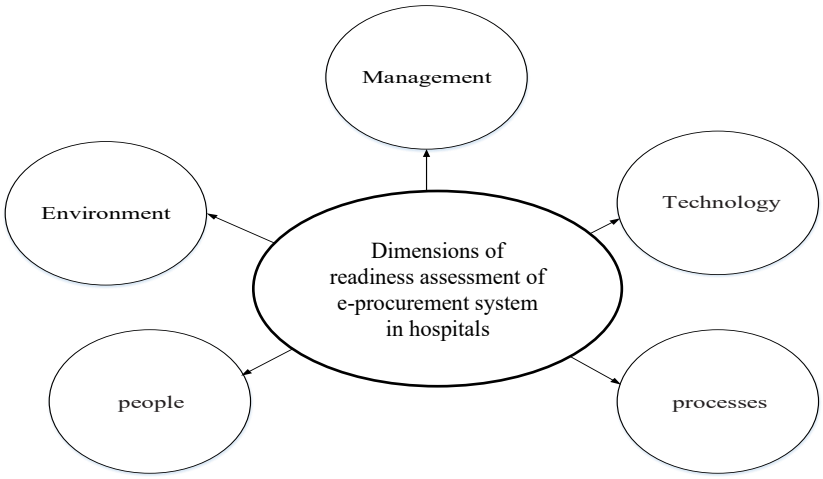


Fig. 1. Evaluation dimensions of e-procurement readiness in hospitals

In regards to the existing e-readiness frameworks, the integration of VERDICT, Mutula and Van Brakel, P3I3 and KPMG models can provide a comprehensive understanding of major dimensions and components affecting the readiness of e-procurement system in hospital systems. The comprehensive model of VERDICT including the main areas of management, technology, process, and human resource covers the majority of important areas of the e-procurement system readiness in an organization (Ruikar *et al*., [29]). In addition, the environmental factor examined in the literature of e-procurement domain is considered as one of the main dimensions of e-readiness assessment in Mutula and Van Brakel model (Mutula & Van Brakel, [30]). P3I3 model places emphasis on the readiness in reengineering activities and e-leadership having an undeniable role in the success of the e-procurement system. Also, reengineering and leadership are subsets of process and management areas respectively. Furthermore, due to the dimensions of risk management, KPMG model has been utilized for project and performance management [31]. Therefore, the framework resulting from the integration of the above models covers basic dimensions and criteria influencing the system readiness in hospitals. The proposed conceptual framework including the readiness dimensions and criteria is presented in Table 3. Also, the conceptual framework presented in this paper is depicted in Figure 2.

Table 3
Evaluation criteria

Dimension	Code	Criteria	Reference
People	PE1	Providing efficient training courses and updating the staff's knowledge in the IT field	Vaidya *et al*., [14]
	PE2	Perception of importance and advantages of employing e-procurement tools by personnel	Ruikar *et al*., [29]
	PE3	Appropriate culture for adaptation to e-procurement	Ruikar *et al*., [29]
	PE4	Having necessary skills and operational experience in applying e-procurement tools by personnel	Vaidya *et al*., [14]
	PE5	Personnel and decision-makers' knowledge in IT domain	Naseebullah *et al*., [37]
	PE6	Transparency of staff's activities in the procurement sector	Ruikar *et al., [*29]
	PE7	ICT employees' awareness of procurement processes	Ruikar *et al*., [29]
	PE8	Encouraging staff to use e-procurement tools	Rui, kar *et al*., [29]
	PE9	Formation of a committee for addressing staff's problems of using the e-procurement tools	Ruikar *et al*., [29]
	PE10	Staff's willingness to employ the e-procurement system	Vaidya *et al*., [14]
Environment	EN1	Government policies for supporting online purchase	Naseebullah *et al*., [37]
	EN2	Competitive policies of the country for motivating the firms	Naseebullah *et al*., [37]
	EN3	Establishment of a legal system and effective regulations for effective use of ICT	Naseebullah *et al*., [37]
	EN4	Supplier's support and commitment	Naseebullah *et al.* [37]
	EN5	Security and reliability of national ICT network	Eadie et *al*., [38]
	EN6	Quality of telecommunication services in country including high-speed internet	Naseebullah *et al*., [37]
	EN7	Appropriate policies for linking the external environment and processes in their internal environment	Naseebullah *et al.,* [37]
	EN8	Leadership and government policy-making	Sangari *et al*., [10]
	EN9	Industry acceptance and suppliers' trust in the e-procurement system	Kaliannan *et al*., [39]
Management	MG1	Managers' skills in ICT field	Naseebullah *et al*., [37]
	MG2	Change management	Yusif *et al*. [18]
	MG3	Assignment of required human sources	Naseebullah *et al*., [37]
	MG4	Integrated transportation management for receipt of ordered items	Naseebullah *et al*., [37]
	MG5	Information management for integrating information in system	Naseebullah *et al*., [37]
	MG6	Top managers' active participation in implementation and strategy development	Vaidya *et al*., [14]
	MG7	Illustration of e-procurement strategies in whole levels by management	Vaidya *et al*., [14]
	MG8	Managers' expertise in process reengineering	Gunasekaran *et al*., [23]
	MG9	Inventory management and investigating supply chain assets	Gunasekaran *et al*., [23]
	MG10	Managers' knowledge of environmental factors	Gunasekaran *et al*., [23]
	MG11	Risk management in different conditions	Veit *et al*., [40]
	MG12	Project management	Vaidya *et al*., [14]
	MG13	Calculating the Rate of Return on investment and cost evaluation	Gunasekaran *et al*., [23]
	MG14	Top management commitment to implementing e-procurement system	Vaidya *et al*., [14]
	MG15	The ratio of the number of employees to existing computers	Gunasekaran *et al*., [23]
	MG16	Allocation of required financial resources for using e-procurement tools	Tran *et al*., [41]
	MG17	Appropriate policies in relation to the utilization of ICT	Panayiotou *et al*., [22]
	MG18	Assessment and confirmation of suppliers	Panayiotou *et al*., [22]

Table 3
Continued

Dimension	Code	Criteria	Reference
Technology	IT1	Adequate infrastructure in the ICT sector	Mauco *et al*., [42]
	IT2	Appropriate security system of ICT for security of data transfer	Naseebullah *et al*., [37]
	IT3	Adequate IT support such as suitable speed and quality	Naseebullah *et al*., [37]
	IT4	Flexibility of current systems in the ICT sector for adaptation to changes and fast technology development	Naseebullah *et a*l., [37]
	IT5	Use of advanced telecommunication and network technologies such as optical fiber and wireless network	Naseebullah *et al*., [37]
	IT6	Providing services via a portal such as access to records, correspondence, and any kind of exchange of information	Naseebullah *et al*., [37]
Process	PR1	Performance measurement of various process	Vaidya *et al*., [14]
	PR2	Designing web-based procurement processes	Ruikar *et al*., [29]
	PR3	Adaptation to e-procurement tools to resolve the weaknesses of the procurement process	Naseebullah *et al*., [37]
	PR4	Integration and standardization of procurement processes	Vaidya *et al*., [14]
	PR5	Application of analysis tools and improvement techniques	Ruikar *et al*., [29]
	PR6	Continuous monitoring of system performance for improving the processes	Vaidya *et al*., [14]
	PR7	Process reengineering and changing the existing pattern of processes	Vaidya *et al*., [14]
	PR8	Process automation	Ruikar *et al*., [29]
	PR9	Identifying the challenges and obstacles to utilizing e-procurement system	Ruikar *et al*., [29]
	PR10	Use of web-based tools for overcoming inefficiencies of existing processes	Ruikar *et al*., [29]

3. Methodology

The integration of Grey Relational Analysis and Fuzzy Decision Map approach is employed in this paper. The Grey Relational Analysis is applied to remove the less important variables and to evaluate the readiness of the e-procurement system in hospital. The Fuzzy Decision Map is used to analyze the relationships between factors and to calculate the final weight of factors.

3.1 Grey Relational Analysis (GRA)

In grey system theory, all natural and social systems are uncertain systems, composed of several types of uncertainties and noises as a result of disturbances from both internal and external sources, or as a result of human knowledge and cognition limitations. Having incomplete information about the system or insufficient data is one of the fundamental characteristics of uncertain systems. It is possible for a system to have incomplete information regarding its elements (parameters), structure, boundaries, and behaviors (Peng *et al*., [8]).

The fundamental concept of Grey refers to information that is incomplete. In gray system theory, 'white' represents information that is entirely known, 'black' represents information that is completely unknown, and "grey" represents information that is partially known and partially unknown. Gray systems are defined as systems with incomplete information (Kocak *et al*., [43]).

GRA is a tool based on grey system theory developed by Deng *et al*. (2000) for analyzing the relationship between a reference series and other series. GRA aims to measure the similarity between the compared series. Besides, it should be noted that this method solves the problem by the integration of all values of performance indicators into a single value. This characteristic transforms the original problem into a single attribute decision problem and increases performance accuracy. Another reason for applying this method is that it can better separate the variables being

evaluated regardless of some performance evaluation methods such as Data Envelopment Analysis. (Kuo *et al*., [44]). In addition, this approach has no limitation in regard to the sample size and normality of data distribution and has a simple calculation method (Tseng *et al*., [45]). The GRA methodology is in accordance with reference (Nilashi *et al*., [46]).

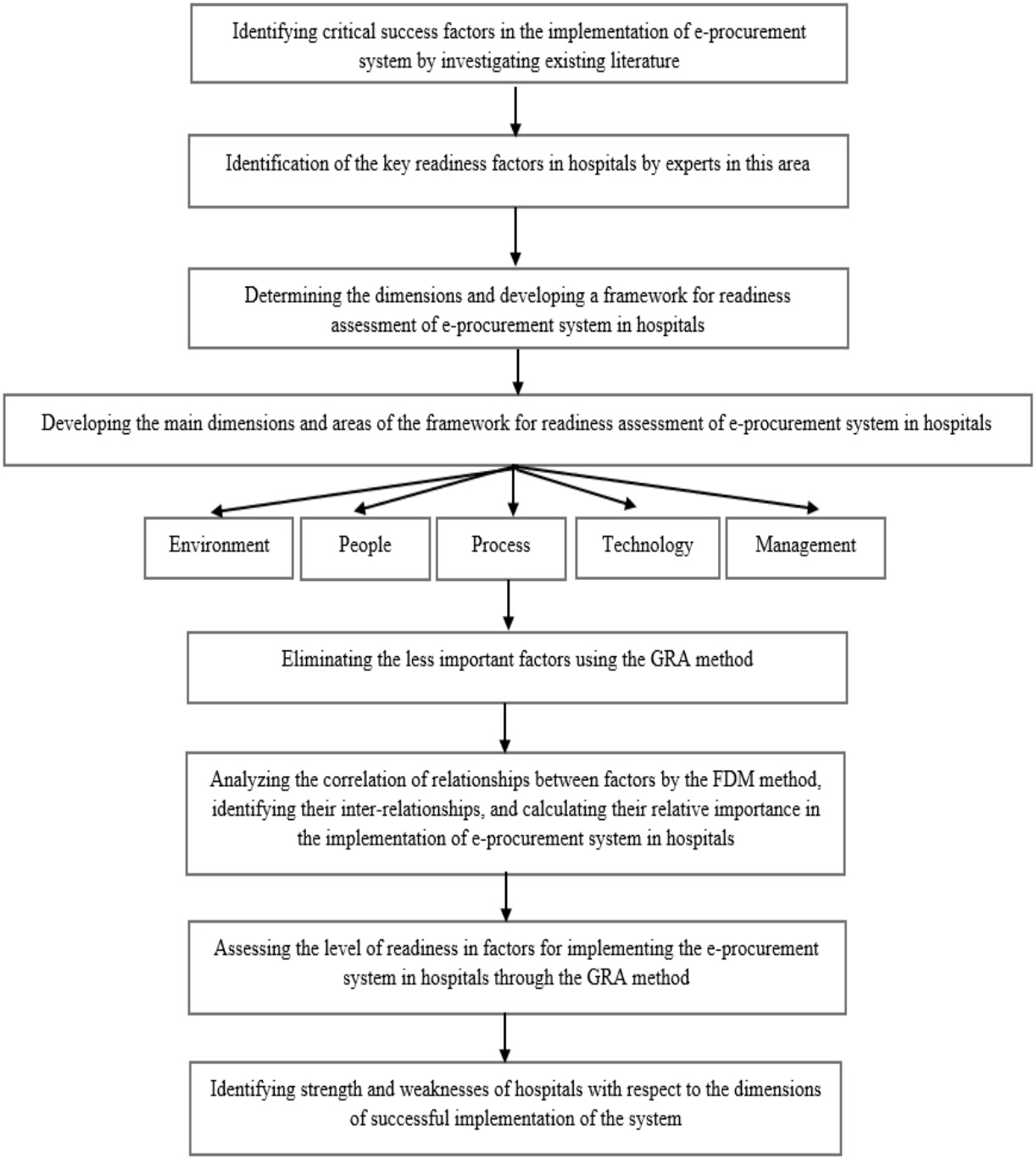


Fig. 2. Conceptual framework for e-procurement readiness assessment in hospitals

3.2 Fuzzy decision map (FDM)

The FDM method was introduced in 2006 to solve the weaknesses and complexities of Analytical Network Process (ANP) methods as well as the problems related to the feedback and relations between criteria. The main constraint of ANP is that its results depend on network structure and

different structures may have disparate results. The FDM method can indicate the feedback of factors along with nonlinear relations and also decides the effects of criteria on each other instead of asking mundane questions in ANP (Tzeng *et al*., [47]). The FDM method includes calculating the local weights, forming the adjacency matrix by using the Fuzzy Cognitive Map (FCM) method, calculation of the normalized stability matrix, and calculation of the total weights. The details of the FDM methodology has been discussed in some previous studies (Elomda *et al*., [48, 49]).

4. Case study

We conducted a case study in 2020 in one of the specialty hospitals located in Tehran, Iran. This hospital is one of the largest specialty medical centers in Iran that serves a large number of patients every day. It has a high ranking in Iran's hospital ratings. In addition to the health services, it has scientific interactions with other major research centers due to its significant educational and research activities. Since one of the main parts of this hospital is the supply sector, implementing the e-procurement system in this hospital provides significant benefits such as the reduction in costs, increase in speed and better services. Considering the problems and obstacles to implementing e-procurement in hospital alongside high costs of failure of system implementation, evaluation of hospital readiness has great importance prior to the implementation of this system and for this purpose, an appropriate readiness assessment framework needs to be developed.

The procurement process has disparate parts in this hospital ranging from general items (e.g., pen, paper, pencil, etc.), IT-related items, and technical engineering items (i.e., iron as well as the heating and cooling system), to medical equipment (medical consumables such as medicine, syringe, serum, etc.). General items, technical engineering, IT and capital equipment are managed in a separate unit and there is a distinct unit for medical consumables. Data has been collected from 13 experts working in healthcare, ICT, and supply departments of the hospital. The experts' expertise and work experience are given in Table 4.

Table 4
Characteristics of experts in the studied hospital

Number	Work experience	Expertise
2	5-10 Years	Hospital ICT
3	10-20 Years	Supply chain of hospital systems
2	15-20 Years	Warehousing
1	15 Years	Distribution
2	10-25 Years	Medical equipment
2	10-15 Years	Non-medical equipment
1	25 Years	Accounting

Based on the type of research, three questionnaires have been designed as described in the following:

i. The first questionnaire has five main criteria and 53 factors or questions. Drawing upon this questionnaire, the importance of each criterion and sub-criterion is evaluated and the less important factors are removed by using the GRA approach. The obtained results of this questionnaire contribute to accurately assessing the hospital readiness for implementing the e-procurement system through 7-point Likert scales.
ii. The second questionnaire includes five major criteria and 26 factors. In the first question, the weights of the factors are extracted by applying the AHP approach and in the second one, the adjacency or correlation matrix is obtained based on the FCM method. Through mentioned questions and methods, the correlation of the relationships between factors

is analyzed and also the final weights of the factors are calculated. The causal relationships between factors in the implementation of e-procurement system in the hospital are assessed through the FDM method. The assessment scales of factors in the first question (AHP) and the second one (FDM) follow the 9-point Likert scales ranging from Extreme importance to Equal importance.

iii. The third questionnaire including five criteria and 26 factors is the output of the first one to measure the readiness of factors through GRA method. The measurement scale of factors in the third questionnaire is the 7-point Likert scales ranging from very high to very low.

4.1 Reducing the number of the factors via the GRA

To remove the factors with less degree of importance, a threshold is determined in the GRA method. Since the obtained average of grey relational grade is 0.71, the threshold value is assumed as 0.71 considering the experts' opinions. In other words, factors with a grey relational grade of less than 0.71 were eliminated due to less importance. The grey relational grade of the factors has been represented in Table 5.

Table 5
The grades of grey relation factors

Grade	Dimensions	Grade	Dimensions
0.77	PR4 *	0.82	MG1 *
0.69	PR5	0.73	MG2 *
0.77	PR6 *	0.75	MG3 *
0.74	PR7 *	0.69	MG4
0.71	PR8 *	0.76	MG5 *
0.70	PR9	0.80	MG6 *
0.67	PR10	0.69	MG7
0.74	PE1 *	0.73	MG8 *
0.73	PE2 *	0.66	MG9
0.71	PE3 *	0.69	MG10
0.69	PE4	0.63	MG11
0.73	PE5 *	0.68	MG12
0.73	PE6 *	0.70	MG13
0.73	PE7 *	0.80	MG14 *
0.69	PE8	0.62	MG15
0.68	PE9	0.74	MG16 *
0.74	PE10 *	0.70	MG17
0.68	EN1	0.68	MG18
0.66	EN2	0.74	IT1 *
0.73	EN3 *	0.72	IT2 *
0.74	EN4 *	0.69	IT3
0.65	EN5	0.68	IT4
0.78	EN6 *	0.66	IT5
0.69	EN7	0.72	IT6 *
0.68	EN8	0.64	PR1
0.74	EN9 *	0.66	PR2
		0.67	PR3

* The more important factors

After calculating the grey relational grade and eliminating the less important factors, 27 factors from the preliminary 53 factors were removed and 26 factors preserved.

4.2 Investigating the inter-relationships between factors and calculation of the total weight of the factors through the FDM

In this section, by applying the FDM method, the inter-relationships and interactions between factors are examined. Considering the importance of each factor, the final weights of the factors are measured. An instance with respect to five main criteria has been presented in Tables 6-9.

After investigating the adjacency matrix and according to Figure 3, it can be concluded that management and environment dimensions are the most influential factors on the other main dimensions. Consequently, if these two factors are in satisfactory conditions, they will have a significant impact on readiness for implementing the e-procurement system.

Table 6
Local weights of the main criteria (Ln)

Local Weights	Dimensions
0.4982	Management (MG)
0.0500	Information Technology (IT)
0.2522	Process (PR)
0.1252	People (PE)
0.0744	Environment (EN)

Table 7
Adjacency matrix of the main dimensions(E)

EN	PE	PR	IT	MG	Dimensions
0	0.30	0.27	0.27	0	MG
0	0	0.28	0.00	0	IT
0	0.25	0	0.24	0	PR
0	0	0.25	0.00	0	PE
0	0	0.20	0.35	0.30	EN

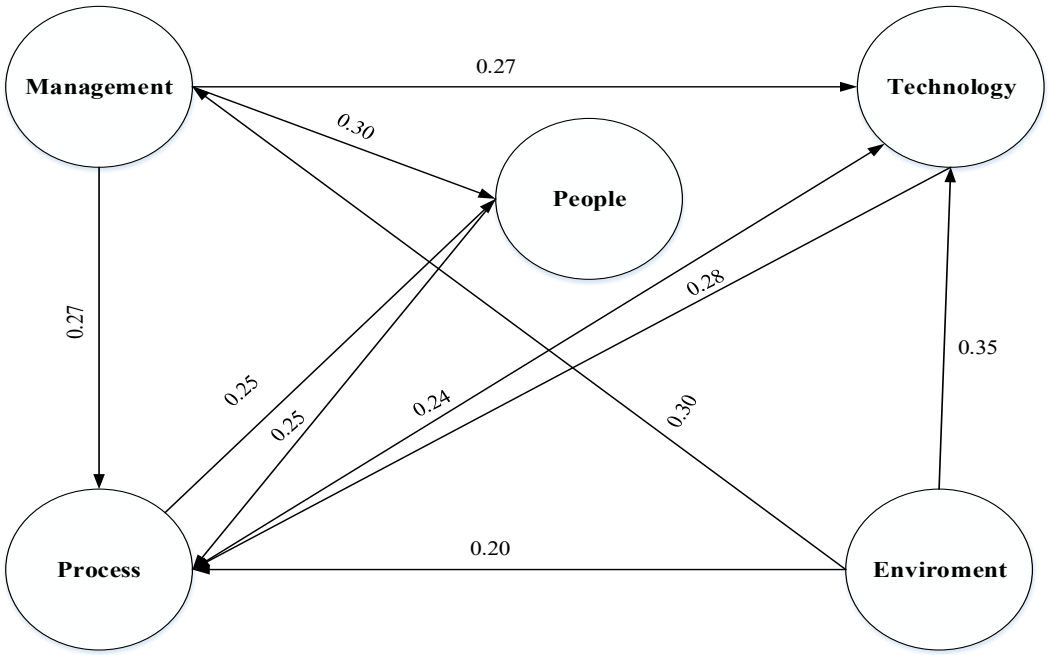


Fig.3. FCM for dimensions

Table 8
Normalized stability matrix of dimensions (C^*_n)

EN	PE	PR	IT	MG	Dimensions
0.1617	0.2115	0.2279	0.2203	0.1738	MG
0.1617	0.1886	0.2262	0.2004	0.1738	IT
0.1617	0.2067	0.2083	0.2171	0.1738	PR
0.1617	0.1885	0.2241	0.2003	0.1738	PE
0.1617	0.1902	0.2237	0.2270	0.1975	EN

According to Table 9, The management and process dimensions are weighed the most, respectively. Therefore, the most important area in the implementation of the e-procurement system in the case hospital is the management dimension based on the identified final weights. After the final weight and interactions for five main criteria were obtained, the local weights and importance rating of 26 sub-criteria can be measured as given in Table 10.

Table 9
Final weights of dimensions

Rank	Normalized final weight $G(C_i)$	Global Weight	Dimensions
1	0.3527	0.6918	MG
5	0.1220	0.2393	IT
2	0.2244	0.4401	PR
3	0.1601	0.3139	PE
4	0.1409	0.2764	EN

Table10
Normalized local weight of factors

L_n	Criteria	L_n	Criteria
0.4235	PR3	0.1288	MG1
0.1309	PR4	0.0670	MG2
0.3344	PE1	0.0377	MG3
0.0494	PE2	0.0664	MG4
0.1357	PE3	0.2172	MG5
0.0511	PE4	0.2686	MG6
0.2158	PE5	0.1705	MG7
0.0444	PE6	0.0438	MG8
0.1693	PE7	0.7617	IT1
0.2476	EN1	0.1729	IT2
0.2530	EN2	0.0654	IT3
0.2361	EN3	0.3645	PR1
0.2634	EN4	0.0810	PR2

In regard to the above figure (Figure 4), managers' expertise in the ICT area and process reengineering are the most influential factors in the implementation of the e-procurement system. So, factors with maximum output exert a profound effect on efficient e-procurement implementation.

Based on Figure 5, the maximum effect is associated with the IT infrastructure in the hospital, which is the main pre-condition for e-procurement system implication.

As depicted in Figure 6, continuous monitoring of performance of the e-procurement system has the highest effect on other factors and as a result, the case hospital needs to be prepared for this factor to implement the system.

According to Figure 7, accomplishing efficient training courses and updating staff knowledge in IT domain have the greatest influence on other factors and increase the staff's awareness and perception of the importance of e-procurement system as well as their willingness to use this system.

As displayed in Figure 8, quality of telecommunication services is one of the main pre-conditions for implementation of the e-procurement system and has the highest influence on other factors. For this reason, if this quality is considerable, the health policies for utilizing the system will be efficient and also suppliers will be more inclined to use this system.

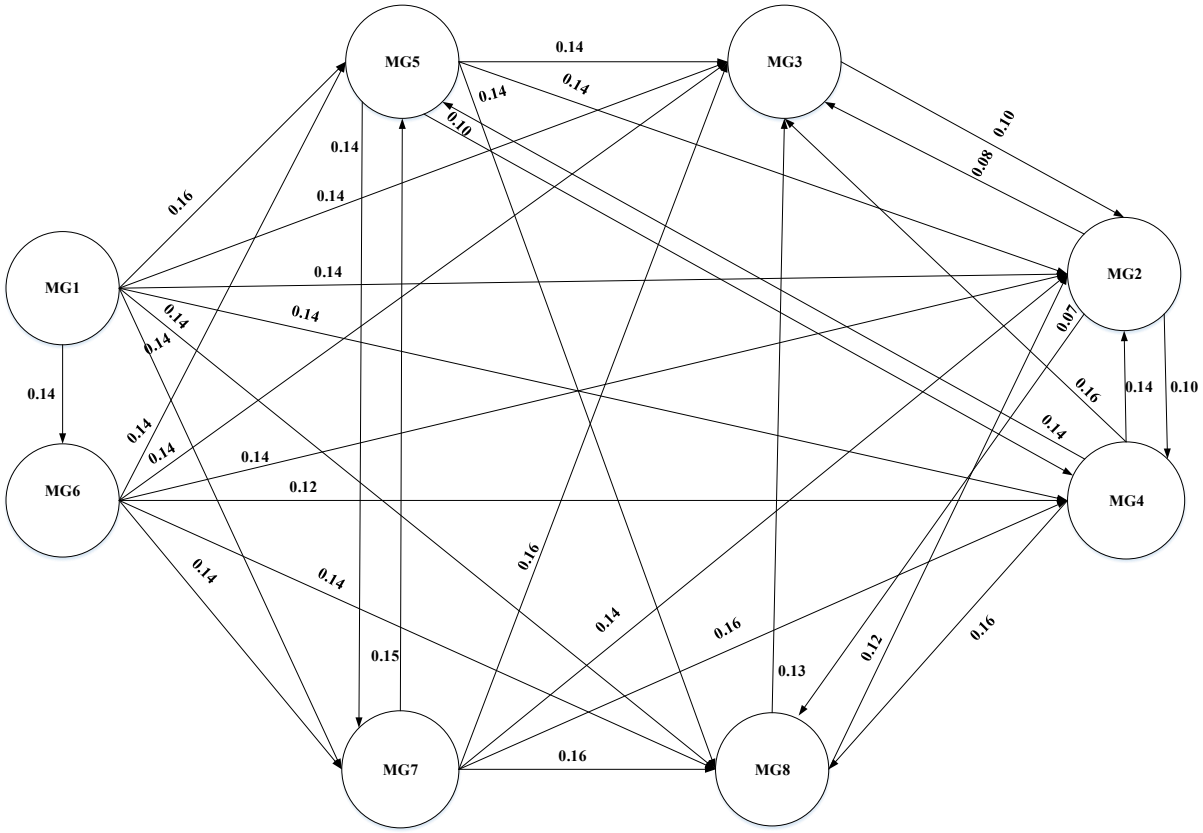


Fig. 4. FCM for management-related criteria

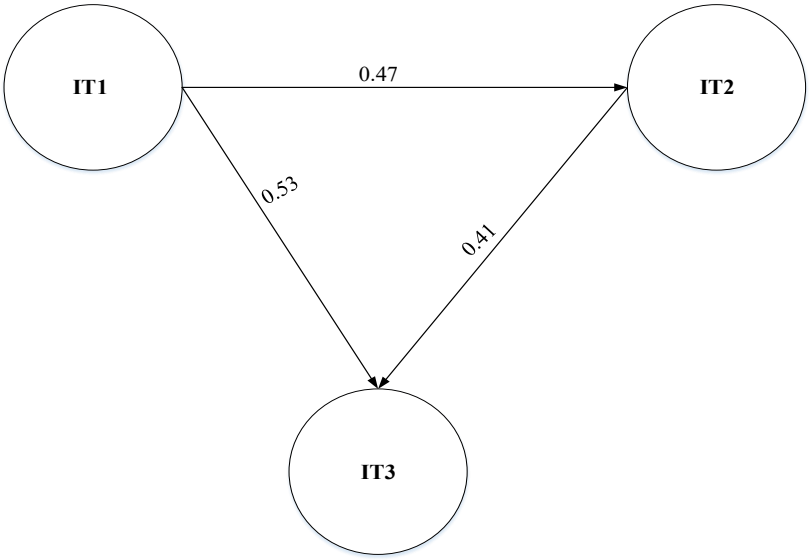


Fig.5. FCM for technology-related criteria

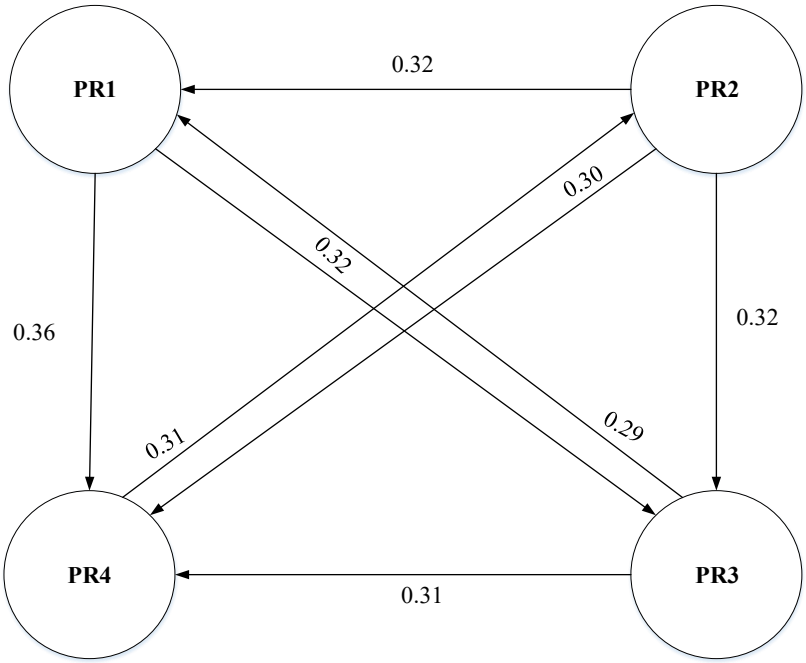


Fig.6. FCM for process-related criteria

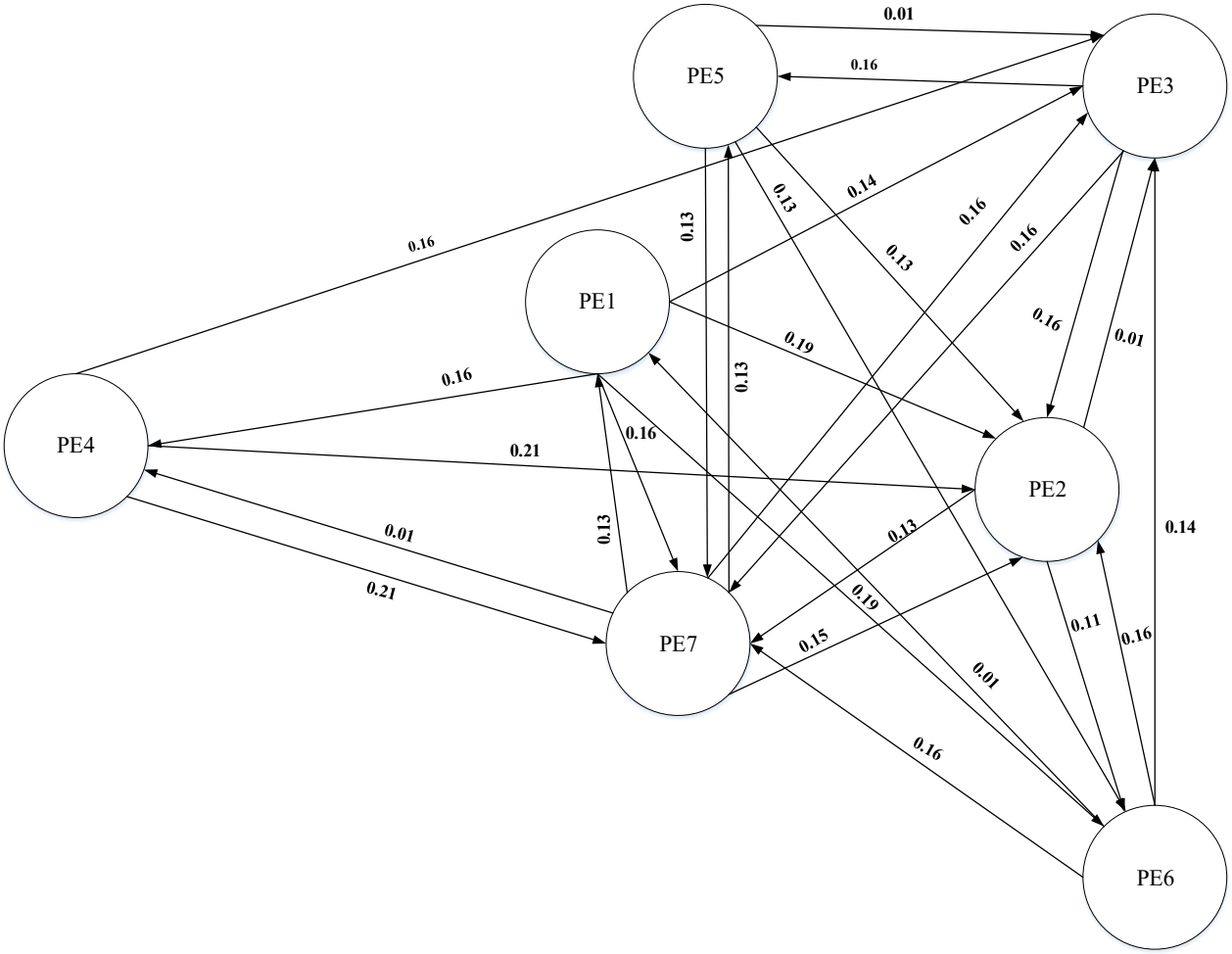


Fig. 7. FCM for people-related criteria

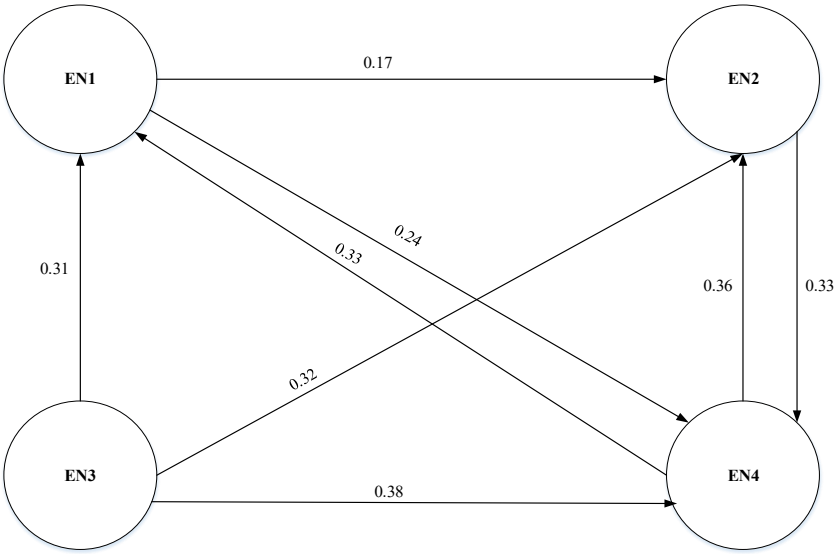


Fig. 8. FCM for environment-related criteria

After obtaining the final weights of sub-criteria, in regard to the effect on the logistic threshold function presented in Table 11, the main sub-criteria with the highest weights for implementing the e-procurement system are identified and presented in Table 13. The most influential factors have been illustrated in Table 12. It should be noted that the effect of factors must be distinguished from the final weight of factors. Factors with maximum effect are the bottlenecks and key characteristics of the system. For instance, in the environment dimension, quality of telecommunication services in the country is the most influential factor while industry acceptance and suppliers' trust in the e-procurement system are the most important ones. This means that suppliers will not trust as long as telecommunication services are not appropriate and the precondition for suppliers' acceptance is the quality of the country's telecommunication. But, if the telecommunication services are suitable in the country, the most significant factor in implementing e-procurement system is suppliers' confidence in this system.

Table 11
Final weights of criteria by using logistic threshold function

Rank	β_{ij}	Criteria	Rank	β_{ij}	Criteria
1	0.0751	PR3	4	0.0455	MG1
3	0.0424	PR4	6	0.0331	MG2
1	0.0386	PE1	7	0.0277	MG3
6	0.0151	PE2	5	0.0334	MG4
4	0.0223	PE3	2	0.0609	MG5
5	0.0154	PE4	1	0.0706	MG6
2	0.0287	PE5	3	0.0525	MG7
7	0.0148	PE6	8	0.0289	MG8
3	0.0252	PE7	1	0.0698	IT1
4	0.0347	EN1	2	0.0298	IT2
2	0.0350	EN2	3	0.0224	IT3
3	0.0349	EN3	2	0.0689	PR1
1	0.0363	EN4	4	0.0381	PR2

Table 12
The most influential factors in implementing the e-procurement system in the case hospital

Dimension	Most influential factors
Management (MG)	Managers' expertise in the ICT and their skills in process reengineering
Information Technology (IT)	Appropriate ICT infrastructure in hospital
Process (PR)	Continuous monitoring of performance of the e-procurement system
People (PE)	Providing efficient training courses and updating staff's knowledge in the IT domain
Environment (EN)	Quality of telecommunication services in the country

Table 13
The most important factors in implementing the e-procurement system in the case hospital

Dimension	Most important factors
Management (MG)	Managers' skills in process reengineering - top managers' active participation in implementing the e-procurement system - managers' expertise in the ICT domain
Information Technology (IT)	Appropriate ICT infrastructure
Process (PR)	Process reengineering and changing existing patterns - standardization and integration of procurement processes
People (PE)	Conducting efficient training courses and updating staff's knowledge in the IT domain
Environment (EN)	Industry acceptance and suppliers' confidence in e-procurement system

4.3 Evaluation of hospital readiness for implementing e-procurement system

In this section, hospital readiness is assessed in various aspects to implement e-procurement system. For this purpose, based on the acquired data from the third questionnaire and based on the GRA method, hospital readiness is evaluated in each of the factors associated with main dimensions.

As shown in Table 14 and Table 11, it can be concluded that factors with higher weights require higher readiness. These factors must be prioritized over other factors for increasing their readiness if their readiness is low. The readiness assessment in each of the dimensions has been analyzed separately as follows:

i. In the management dimension, the readiness of managers' skills in process reengineering for implementing e-procurement system is relatively low and should be strengthened.
ii. The main factor in technology dimension is appropriate infrastructure of ICT in hospital. This significant factor has a readiness level of 0.5, which is considered moderate, so it should be improved. Besides, the readiness of the other two important factors in this dimension is less in comparison to the infrastructure but since the significance of these two factors is lower than hospital infrastructure, increasing the readiness of the ICT infrastructure is a high priority. For a successful e-procurement system, the other two factors must be considered carefully and improved.
iii. The key factors in process dimension are process reengineering and change of existing model as well as integration and standardization of procurement processes. Except the readiness for process automation which is moderate, the readiness of these two mentioned factors is low. Due to this, their readiness should be enhanced to facilitate e-procurement implementation
iv. The primary factors in human resource dimension include planning for training courses, updating employees' knowledge in the IT domain, and then the transparency of staff's activities in the procurement sector. The hospital readiness for organizing training courses is rather good. The readiness of other factors associated with this area is different. The readiness of the factors such as appropriate organizational culture and also employees' knowledge in the IT domain is poor and the readiness in other factors is moderate and

medium-low. To effectively implement the system, it is important to arrange the necessary conditions to increase readiness for these factors.

v. The existing factors in the environment dimension have the same importance practically, but their level of readiness is different in the case hospital. The principal factor in this dimension is industry acceptance and suppliers' confidence in the e-procurement system and the lowest readiness for implementing e-procurement system belongs to this factor. Thus, the required steps need to be taken to convince suppliers and gain their trust in this system.

Table 14
The hospital readiness in different aspects

Grade	Criteria	Grade	Criteria
0.40	PR3	0.44	MG1
0.50	PR4	0.43	MG2
0.51	PE1	0.48	MG3
0.49	PE2	0.44	MG4
0.45	PE3	0.42	MG5
0.45	PE4	0.44	MG6
0.45	PE5	0.46	MG7
0.47	PE6	0.46	MG8
0.48	PE7	0.50	IT1
0.45	EN1	0.45	IT2
0.52	EN2	0.45	IT3
0.46	EN3	0.41	PR1
0.45	EN4	0.40	PR2

5. Conclusions

Organizational readiness for change is a vital pre-condition for successful implementation of complex reforms in the healthcare domain. However, there were no comprehensive models for the readiness of the e-procurement system, especially in the healthcare and hospitals. Toward this end, a comprehensive framework was developed to evaluate hospital readiness for e-procurement. The objective of this paper is to identify the readiness of hospitals in various areas, to identify influential factors and their interrelationships, and to assess how important these factors are in determining the readiness of hospitals to successfully implement the system and to increase readiness. First, the key factors in successful implementation of the e-procurement system were identified in this paper. In the second step, 53 critical success factors were obtaining through literature and opinions of experts in healthcare, procurement, and ICT domains. The identified factors were then categorized into five main dimensions (Figure 1). In the third step, the factors with less importance rating were removed by applying the GRA method and 26 out of 53 factors were preserved. In the next step, the inter-relationships between remaining factors, their mutual effects, as well as their relative importance were examined by applying the FDM method.

By investigating the impacts of readiness factors on each other, those with the highest impact on the hospital readiness for successful implementation of the e-procurement system were explored in their respective groups. Therefore, the factors mentioned above are bottlenecks in implementing the system at the case hospital and should be taken into account to implement the system successfully. In the logistics threshold function, the FDM approach resulted in the highest weights for the management and process dimensions, respectively. In the same manner, the primary readiness factors in implementing the e-procurement system were pinpointed in the case hospital.

Finally, after readiness evaluation of the e-procurement system in the case hospital, it was concluded that the readiness of all dimensions and especially the factors with highest effect and importance to the successful implementation of the system is relatively unsatisfactory and appropriate practices need to be adopted to improve readiness in these factors. Nevertheless, particular attention must be paid to all of the factors to improve level of readiness in order to successfully implement the e-procurement system.

Given the obtained results, it is necessary to note that different factors influence successful implementation of e-procurement system and focusing only on technology aspects cannot help hospitals benefit from such systems effectively. Also, it is recommended that the identified readiness factors need to be considered based on the priorities and their respective weights. Hence, the system implementation will be much more likely achieve organizational goals.

A few study limitations should be noted. In developing countries, high quality health care facilities are not uniformly distributed in all areas. Hence, there is a possibility that the present results may not be generalizable to other Iranian healthcare facilities. Our study only covered one major hospital in Tehran, accounting only for 20 percent of entire city population. The results and the framework presented in this paper can be employed to assess the system readiness in other healthcare providers to make improvements for successful implementation of the system and compare with the results acquired in this paper.

Acknowledgement
This research was not funded by any grant.

Conflicts of Interest
There are no conflicts of interest between authors.

References
[1] Matthews, S., & Roxas, R. (2023). Private equity and its effect on patients: A window into the future. International Journal of Health Economics and Management, 23(4), 673–684. https://doi.org/10.1007/s10754-022-09331-y
[2] Saha, E., Rathore, P., & Anne, B. (2022). E-procurement: An emerging tool for pharmaceutical supply chain management. In International Conference on Data Analytics in Public Procurement and Supply Chain (pp. 12–24). Springer. https://doi.org/10.1007/978-981-99-1019-9_12
[3] Adjei-Bamfo, P., Maloreh-Nyamekye, T., & Ahenkan, A. (2019). The role of e-government in sustainable public procurement in developing countries: A systematic literature review. Resources, Conservation and Recycling, 142, 189–203. https://doi.org/10.1016/j.resconrec.2018.12.001
[4] Bahaddad, A. A., Alharbi, L. M., Alghamdi, A. M., & Almarhabi, K. A. (2018). Factors attracting online consumers to choose e-Malls for e-procurement in Saudi Arabia. Enterprise Information Systems, 12(7), 856–887. https://doi.org/10.1080/17517575.2015.1091952
[5] Balasubramanian, S., Shukla, V., Sethi, J. S., Islam, N., & Saloum, R. (2021). A readiness assessment framework for Blockchain adoption: A healthcare case study. Technological Forecasting and Social Change, 165, 120536. https://doi.org/10.1016/j.techfore.2020.120536
[6] Hasni, M., Aguir, A., & Ben Amor, M. (2022). Hybrid model for a cross-department efficiency evaluation in healthcare systems. Managerial and Decision Economics, 43(5), 1311–1329. https://doi.org/10.1002/mde.3456
[7] Liu, A., Wang, X., & Xu, N. (2019). A GRA-based method for evaluating medical service quality. IEEE Access, 7, 34252–34264. https://doi.org/10.1109/ACCESS.2019.2903684
[8] Peng, X., Liu, Y., & Zhang, Y. (2021). Ranking the healthcare resource factors for public satisfaction with health system in China—Based on the grey relational analysis models. International Journal of Environmental Research and Public Health, 18(3), 995. https://doi.org/10.3390/ijerph18030995
[9] Javed, S. A., Mahmoudi, A., & Liu, S. (2020). Grey absolute decision analysis (GADA) method for multiple criteria group decision-making under uncertainty. International Journal of Fuzzy Systems, 22(4), 1073–1090. https://doi.org/10.1007/s40815-020-00827-8

[10] Sangari, M. S., Razmi, J., & Gunasekaran, A. (2016). Critical factors for achieving supply chain agility: Towards a comprehensive taxonomy. International Journal of Industrial and Systems Engineering, 23(3), 290–310. https://doi.org/10.1504/IJISE.2016.076870
[11] Adjei-Bamfo, P., Maloreh-Nyamekye, T., & Ahenkan, A. (2020). An e-government framework for assessing readiness for public sector e-procurement in a lower-middle income country. Information Technology for Development, 26(4), 742–761. https://doi.org/10.1080/02681102.2020.1769542
[12] Barajei, C., Adjei-Bamfo, P., & Ahenkan, A. (2023). Exploring the anti-corruption abilities of e-procurement in Ghanaian mining companies. The Electronic Journal of Information Systems in Developing Countries, 89(6), e12288. https://doi.org/10.1002/isd2.12288
[13] Althabatah, A., Alghamdi, A., & Bahaddad, A. A. (2024). Fuzzy maturity model for transformative procurement readiness: Procurement 4.0 perspective. In IFIP International Conference on Advances in Production Management Systems (pp. 3–15). Springer. https://doi.org/10.1007/978-3-031-71633-1_3
[14] Vaidya, K., Sajeev, A. S. M., & Callender, G. (2006). Critical factors that influence e-procurement implementation success in the public sector. Journal of Public Procurement, 6(1/2), 70–99. https://doi.org/10.1108/JOPP-06-01-02-2006-B004
[15] Angeles, R., & Nath, R. (2007). Business-to-business e-procurement: Success factors and challenges to implementation. Supply Chain Management: An International Journal, 12(2), 104–115. https://doi.org/10.1108/13598540710737299
[16] Leipold, K., Klemow, J., Holloway, F., & Markov, S. (2017). World Bank e-Procurement for the selection of consultants: Challenges and lessons learned. In International Handbook of Public Procurement (pp. 511–526). Routledge. https://doi.org/10.4324/9781315092539-28
[17] Tutu, S. O., Adjei-Bamfo, P., & Ahenkan, A. (2019). Evaluating critical factors for the implementation of e-procurement in Ghana. International Journal of Procurement Management, 12(1), 1–14. https://doi.org/10.1504/IJPM.2019.096994
[18] Yusif, S., Hafeez-Baig, A., & Soar, J. (2020). An exploratory study of the readiness of public healthcare facilities in developing countries to adopt health information technology (HIT)/e-Health: The case of Ghana. Journal of Healthcare Informatics Research, 4(2), 189–214. https://doi.org/10.1007/s41666-020-00070-8
[19] Nguyen, T. H., Newby, M., & Macaulay, M. J. (2015). Information technology adoption in small business: Confirmation of a proposed framework. Journal of Small Business Management, 53(1), 207–227. https://doi.org/10.1111/jsbm.12058
[20] Altayyar, A., & Beaumont-Kerridge, J. (2016). External factors affecting the adoption of e-procurement in Saudi Arabian's SMEs. Procedia-Social and Behavioral Sciences, 229, 363–375. https://doi.org/10.1016/j.sbspro.2016.07.147
[21] Brandon-Jones, A., & Kauppi, K. (2018). Examining the antecedents of the technology acceptance model within e-procurement. International Journal of Operations & Production Management, 38(1), 22–42. https://doi.org/10.1108/IJOPM-06-2015-0346
[22] Panayiotou, N. A., Gayialis, S. P., & Tatsiopoulos, I. P. (2004). An e-procurement system for governmental purchasing. International Journal of Production Economics, 90(1), 79–102. https://doi.org/10.1016/S0925-5273(03)00103-8
[23] Gunasekaran, A., & Ngai, E. W. T. (2008). Adoption of e-procurement in Hong Kong: An empirical research. International Journal of Production Economics, 113(1), 159–175. https://doi.org/10.1016/j.ijpe.2007.04.012
[24] Afolabi, A., Ojelabi, R., Oyeyipo, O., & Tunji-Olayeni, P. (2019). Critical success factors (CSFs) for e-Procurement adoption in the Nigerian construction industry. Buildings, 9(2), 47. https://doi.org/10.3390/buildings9020047
[25] Wimalasena, N. N., & Gunatilake, S. (2018). The readiness of construction contractors and consultants to adopt e-tendering: The case of Sri Lanka. Construction Innovation, 18(3), 350–370. https://doi.org/10.1108/CI-03-2017-0025
[26] Ali, R., & Abbas, M. (2019). User's E-readiness for E-health and traditional healthcare: A case of Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan. International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies, 10(5), 607–615.
[27] Fathian, M., Akhavan, P., & Hoorali, M. (2008). E-readiness assessment of non-profit ICT SMEs in a developing country: The case of Iran. Technovation, 28(9), 578–590. https://doi.org/10.1016/j.technovation.2008.02.002
[28] Chipembele, M., & Bwalya, K. J. (2016). Assessing e-readiness of the Copperbelt University, Zambia: Case study. The International Journal of Information and Learning Technology, 33(5), 315–332. https://doi.org/10.1108/IJILT-12-2015-0036
[29] Ruikar, K., Anumba, C. J., & Carrillo, P. M. (2006). VERDICT—An e-readiness assessment application for construction companies. Automation in Construction, 15(1), 98–110. https://doi.org/10.1016/j.autcon.2005.02.009

[30] Mutula, S. M., & Van Brakel, P. (2006). An evaluation of e-readiness assessment tools with respect to information access: Towards an integrated information-rich tool. International Journal of Information Management, 26(3), 212–223. https://doi.org/10.1016/j.ijinfomgt.2006.02.004
[31] Memarzadeh, G., & Jahany, A. (2014). The presenting a model for municipalities e-readiness assessment.
[32] Sun, B., Jiang, J., Zheng, F., & Sun, T. (2015). Practical state of health estimation of power batteries based on Delphi method and grey relational grade analysis. Journal of Power Sources, 282, 146–157. https://doi.org/10.1016/j.jpowsour.2015.01.106
[33] Javed, S. A., Liu, S., Mahmoudi, A., & Nawaz, M. (2019). Patients' satisfaction and public and private sectors' health care service quality in Pakistan: Application of grey decision analysis approaches. The International Journal of Health Planning and Management, 34(1), e168–e182. https://doi.org/10.1002/hpm.2629
[34] Arici, E., Kocaman, B., & Uzun, S. (2025). Multi-objective optimization of a pond aeration system using Taguchi-based gray relational analysis. Aquaculture International, 33(1), 50. https://doi.org/10.1007/s10499-024-01758-z
[35] Chen, P.-T., & Yang, C.-J. (2024). Using Taguchi method and gray relational analysis to enhance manufacturing performance in photopolymerization. Progress in Additive Manufacturing, 9(6), 2393–2402. https://doi.org/10.1007/s40964-024-00593-1
[36] Elumalai, R., Subramanian, S., & Kumar, S. (2024). Experimental investigation and gray relational optimization of engine parameters to improve the output characteristics of an ammonia biodiesel powered dual fuel combustion engine. Case Studies in Thermal Engineering, 56, 104197. https://doi.org/10.1016/j.csite.2024.104197
[37] Naseebullah, L., Khan, S. A., & Khan, M. A. (2012). An empirical investigation of organisational e-readiness impact on e-procurement implementation. International Journal of Logistics Systems and Management, 12(4), 412–432. https://doi.org/10.1504/IJLSM.2012.048367
[38] Eadie, R., Perera, S., & Heaney, G. (2010). Identification of e-procurement drivers and barriers for UK construction organisations and ranking of these from the perspective of quantity surveyors. Journal of Information Technology in Construction, 15, 23–43.
[39] Kaliannan, M., Awang, H., & Raman, M. (2007). Technology adoption in the public sector: An exploratory study of e-government in Malaysia. In Proceedings of the 1st International Conference on Theory and Practice of Electronic Governance (pp. 1–6). ACM. https://doi.org/10.1145/1328057.1328103
[40] Veit, D. J., Parasie, N. P., & Huntgeburth, J. C. (2011). E-procurement adoption at the municipal level: Influence of organizational, technological and environmental factors. In 2011 44th Hawaii International Conference on System Sciences (pp. 1–10). IEEE. https://doi.org/10.1109/HICSS.2011.177
[41] Tran, Q., Nguyen, H., & Dang, T. (2011). A construction enterprise's readiness level in implementing e-procurement: A system engineering assessment model. Systems Engineering Procedia, 2, 131–141. https://doi.org/10.1016/j.sepro.2011.10.016
[42] Mauco, K. L., Scott, R. E., & Mars, M. (2018). Critical analysis of e-health readiness assessment frameworks: Suitability for application in developing countries. Journal of Telemedicine and Telecare, 24(2), 110–117. https://doi.org/10.1177/1357633X16686548
[43] Koçak, D., & Özer, M. A. (2022). Comparing the quality of governance across the European Union member countries: A grey relational analysis approach. Policy Studies, 43(5), 1135–1155. https://doi.org/10.1080/01442872.2021.1994135
[44] Kuo, Y., Yang, T., & Huang, G.-W. (2008). The use of grey relational analysis in solving multiple attribute decision-making problems. Computers & Industrial Engineering, 55(1), 80–93. https://doi.org/10.1016/j.cie.2007.12.002
[45] Tseng, P., Lin, F., & Feng, C. (2003). The analysis of human and vehicle factors for Taiwan freeway traffic accidents. Journal of the Eastern Asia Society for Transportation Studies, 5, 2470–2482.
[46] Nilashi, M., Zakaria, R., Ibrahim, O., Majid, M. Z. A., & Zin, R. M. (2015). MCPCM: A DEMATEL-ANP-based multi-criteria decision-making approach to evaluate the critical success factors in construction projects. Arabian Journal for Science and Engineering, 40, 343–361. https://doi.org/10.1007/s13369-014-1529-1
[47] Tzeng, G.-H., Chiang, C.-H., & Li, C.-W. (2010). Fuzzy decision maps: A generalization of the DEMATEL methods. Soft Computing, 14, 1141–1150. https://doi.org/10.1007/s00500-009-0507-0
[48] Elomda, B. M., Hefny, H. A., & Hassan, H. A. (2015). MCDM approach based on generalized fuzzy decision map method. In 2015 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE) (pp. 1–8). IEEE. https://doi.org/10.1109/FUZZ-IEEE.2015.7337881
[49] Elomda, B. M., Hefny, H. A., & Hassan, H. A. (2013). An extension of fuzzy decision maps for multi-criteria decision-making. Egyptian Informatics Journal, 14(2), 147–155. https://doi.org/10.1016/j.eij.2013.05.001