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Foresight: a new approach based on the Z-number cognitive map

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Abstract

Foresight has recently emerged as one of the most attractive and practical fields of study, while being used to draw up a preferable future and formulate appropriate strategies for achieving predetermined goals. The present research aimed at providing a framework for foresight with a primary focus on the role of a cognitive approach and its combination with the concept of fuzzy cognitive map in the environments of uncertainty and ambiguity. The proposed framework consisted of the 3 phases: pre-foresight, foresight, and post-foresight. The main stage (foresight) focused on the role of imagination and intuition in drawing the future in the experts' minds and depicting their perceptions above perceptions in the form of a fuzzy cognitive map influenced by variables related to the subject under study in order to determine a preferable future. The use of a Z-number concept and integrating it with fuzzy cognitive maps in the foresight-oriented decision-making space, which was mainly saturated with uncertainty and ambiguity, was one of the main strengths of the proposed framework in the current investigation. The present paper focused primarily on the evolution of expert's knowledge with regard to the topic of foresight. The role of Z-number in various processes, from data collection to illustration, analysis, and aggregation of cognitive maps, was considered for gaining knowledge and understanding into the nature of future. Moreover, an ultimate objective was realized through identifying, aggregating, and selecting the variables from each expert's perspective and then the relationship between each variable was determined in the main stage of foresight. Finally, the proposed framework was presented and explicated in the form of a case study, which revealed satisfactory results.

Keywords: Foresight, Z-number, Cognitive map, Uncertainty

Introduction

Due to the increasing competitions between organizations and paying attention to organizational changes, every organization seeks to have a more effective performance [1]. The role of human resources as the main asset of any companies is very important. Maintenance of human capital has been always one of the concerns of managers, especially in the technology-oriented companies. The leading companies use different methods and tools to maintain and improve their human resources, while taking a strategic approach to this issue. One of these tools and approaches is to have forward thinking in the field of human resources.

Today, foresight is utilized as an effective approach to charting the future state of a company and helping formulate strategies. Being applied to draw up a preferable future and formulate appropriate strategies for achieving predetermined goals, it has recently emerged as one of the most attractive and practical fields of study. Different experts have set out various objectives for foresight, some of which include identification of public technologies, general development priorities, prospection of probable future and drawing landscape development for such a future, timely reduction of negative impacts on or adaptation to the current situation, and exploitation of positive outcomes [2–6]. Depending on the type of activity that takes place in the varied phases

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of foresight framework, possible, plausible, probable, and preferable future trajectories can be generated in the foresight process [7].

Future is an entirely subjective, affiliate-based concept with no external existence. Foresight occurs merely in the mind of an individual obsessed with it and can emerge in the two forms of intuitive and inductive foresight according to the social sciences. While an intuitive forecast is based on those perceptions that transfer from a subconscious to a conscious mind, an inductive forecast is related to the knowledge of the future [8]. Foresight experts have proposed various models, all of which concentrate on a general process for foresight implementation. Accordingly, these frameworks can be employed to carry out foresight in different fields with varied subject domains. The frameworks and processes presented by different experts include the most common types of foresight.

By integrating the concept of Z-number and using opinions of the experts involved in the subject matter under study, the present research sought to present a new conceptual model, namely, identification of the variables affecting the subject and the relationship between those variables for the main stage of foresight. According to the above classification, the new proposed model was labeled as a qualitative one and the involved individuals were the experts functioning within the domain of foresight. The primary challenges in this type of model, which further complicated the issue, were diversification, uncertainty, and ambiguity of the experts' ideas and comments. Application of a cognitive map in the foresight studies could clarify the roles and sequences of the variables in a preferable future and allow for their controllable arrangement to fulfill a predetermined goal. Combining the Z-number approach with cognitive mapping in the prospective studies was one of the innovations of this paper, which could enhance the final model's reliability. The current study sought to mitigate the problem of uncertainty and provide a comprehensive understanding of the variables that affected the subject and the relation between them through combining the Z-number concept and fuzzy cognitive map by using verbal variables and then drawing the conceptual model specific to each expert. The 2nd and 3rd parts of this study will provide the literature review on the subject of foresight and thorough explication of the two concepts of Z-number and fuzzy cognitive maps. The 4th section will present the proposed framework for the main stage of foresight in the field of human resources in a technology-based company. Finally, the paper will end with the discussion and conclusion on the proposed framework.

Literature review

The literature review of foresight studies suggested that the majority of the formerly conducted studies were based on qualitative methods, while combining different approaches to foresight and summarizing experts' opinions. The study of the scholars' views on how to carry out a foresight study revealed how diverse their ideas were.

Various research methods are used in future studies, one of the most important of which is scenario planning, a technique which, by itself, consists of several steps during the implementation process. A panel of experts, Delphi, brainstorming, and environmental scanning are some other approaches involved in foresight and future studies. Most of the scenario analyses have been conventionally qualitative in nature, developing narratives for potential future states. However, scenarios are being increasingly quantified so as to further examine the likely impacts. These methods are combined and integrated during the implementation process. They are divided in different ways, one of the most common methods of which is classification based on the technology used in them. From such a perspective, these methods include the following approaches [9, 10]:

- Numerical or quantitative methods, which are based on the past and present data. The most commonly applied methods are time series, simulation, and econometric models.
- Pseudo-numerical or judgmental methods, which make a group of intermediate qualitative and quantitative approaches and involve quantification of mental judgments through a series of rules and definitions.
- Qualitative methods, in which an expert's opinion is the most reliable factor for drawing future perspectives. The experts express their views based on their evidence or expectations of the future. Some of the most critical sub-categories of these methods include brainstorming, SWOT, Delphi method, scenario planning, retrieval method, and key technologies.

Selection of foresight methods is a multi-factor process. Selecting a proper foresight approach depends on various factors, such as time, available financial resources, and predetermined objectives. The most important criteria for choosing an efficient foresight method are resources, especially money and time, the extent to which experts and stakeholders participate in a project, the need for different methods based on qualitative or quantitative data, suitability of the combination of methods for providing a mutual support, and process-oriented and outcome-oriented expectations we might have for that specific foresight project [11].

The literature review on foresight studies suggests that the majority of the formerly conducted research is based on qualitative methods that combine different approaches to practicing foresight by summarizing expert opinions.

In the study conducted by Popper, from among the varied qualitative methods, literature review, expert panels, and scenarios were shown to be the most utilized approaches taken by researchers, respectively. He listed the various methods used in foresight and identified the criteria for selecting an appropriate method for the problems as well [12].

Bootz et al. [13] categorized 4 types of approaches to foresight: decision support, strategic focus, mobilization, and change management. They examined the links between the French School of Foresight and organizational learning.

The study of the scholars' views on how to carry out a foresight research revealed how diverse their ideas were. The most common and referenced foresight frameworks included Martin, Horton, Reger, Miles, Voros, Saritas, Santo, and Popper. Martin's foresight process consisted of the 3 phases of "pre-foresight," "foresight," and "post-foresight." The pre-foresight involved those steps and measures, which needed to be taken before initiation of the process, including the decision to start a project and preparatory activities [14]. The main stage of foresight involved designing a project, strategic analysis, agreement on feasible options, and dissemination of the project results. The post-foresight phase involved programming an efficient strategy for achieving goals, as well as choosing an approach to publish the results and determine the executives [6]. According to Horton's framework [15], foresight was a 3-step process for expanding the range of possible future development options, including inputs, foresight, outputs, and activities. The information leading to the foundation of the foresight project was gathered from a variety of sources in the first stage. Various methods, such as environmental surveys, Delphi scopes, and systematic studies, were useful to be used here. This information was compared, summarized, and compressed by utilizing various methods, such as scenario planning, graphical comparisons, matrixes, and analysis of interactions. Then, the knowledge derived from the inputs was translated and interpreted. The translated knowledge became organizational perceptions. In the final stage, the perception obtained in the previous stage was evaluated and synchronized to form a commitment to be implemented in the organization. Reger [10] proposed a 7-stage framework for foresight, which included determining information needs, choosing a research area, and selecting information resources, as well as methods and tools, data collection, screening, analysis, interpretation of information, preparation of decisions, evaluation, decision-making, taking an action, and implementation. Miles and Keenan [16] also provided a framework for foresight, which, unlike most models that followed a hierarchical trajectory, had a repeatable process and involved a step-by-step update of results and processes during replication. Pre-foresight, project agent engagement, creation of the future vision, taking an action, and refreshment were the main stages of the foresight project. The framework proposed by Voros [7] involved the 4 vital elements of input, future, output, and strategy. Saritas et al. [17] presented a systematic framework for foresight based on the relationship between the context, content, and process of creating foresight in an organization. They believed that foresight was located and developed in an internal context or a combination of structures, such as internal processes, equipment and technologies, and behaviors, including culture, politics, skills, management, and external texture, incorporating social, technological, economic, ecological, and political systems. By content, they meant thematic areas and creation of the ideas related to those areas during the foresight process. According to Saritas et al. [17], content and texture had to be first identified during the process of foresight projects. This systematic framework was based on 5 activities, including understanding, combination, analysis, selection, and transformation of form and activity. Santo et al. [18] proposed a model, which could be thought of as a development on the works of Horton [15], Conway and Voros [19], and Voros [7]. According to their model, management of foresight activities took into account the 4 crucial stages of goal setting, topic selection, implementation, and decision-making.

Knowledge management has been studied by many researchers based on a futuristic view. Recent methods were found to be reviewed by Bootz et al. [20], who then assessed knowledge management in the field of foresight. Foresight quality could be enhanced by making a knowledge management network as a dynamic capability [21]. The concept of knowledge and its evolution in management, were evaluated by Coulet [22]. Future developments could be predicted by using knowledge management as a tool that played its role, along with the expert knowledge.

The method proposed in this article was one of the qualitative methods, which aimed at increasing the experts' tacit knowledge and gaining their maximum knowledge by helping to remove the ambiguities of their linguistic variables and statements. In general, there were commonalities between the various approaches presented. It is noteworthy to state that this paper introduced a new framework that took into account the main stage of foresight, while relying on Martin's map.

***Fuzzy cognitive map* (*FCM*)**

Tolman was one of the leading cognitive psychologists, who considered cognitive variables for the first time [23]. Axelrod [24] introduced cognitive maps for presenting social science knowledge and a decision-making model in social and political systems [25]. In their diagrams of cognitive maps, the variables or concepts appeared as nodes and the edges played the role of relations between the variables. A cognitive map is drawn with various techniques, including the use of questionnaires to extract expert opinions and map the relationships between the variables, the use of content analysis to explore the relationships in the written texts, the use of quantitative data, and the process of in-depth interviews with different individuals and experts [26–28]. Kosko [29] presented fuzzy cognitive mapping (FCM) as an extension to the cognitive map with a unique potential to model causal and disruptive relationships between the weighted communications. A simple FCM is shown in Fig. 1.

The main superiority of FCM on the cognitive map was defining the power of edges as the sticker of each edge, in which the relationship between the two variables of C_i and C_j was represented by w_{ij}. The power of correlation of relations was written in the form of linguistic variables in the interval of [0, 1] or [−1, +1]. The relationships between the variables based on the graph theory could be converted to the adjacency matrix or communication matrix in the form of $E = [e_{ij}]$ and performed on that mathematical operation [4]. FCM is a method for demonstrating knowledge in systems with uncertainty, ambiguity, and complexity. This model has been used in various applications, such as decision-making, forecasting, strategic planning, engineering science, project management, investment analysis, medicine, and biology [30–34].

Real-world issues are usually faced with uncertainty and incompleteness. Uncertainty is based on inaccuracy, incompleteness, indeterminacy, judgments, obscurity in relation to the data, non-existence of the data on knowledge, and/or the stochastic nature of events. Individual cognitive maps derived from individual domains can be merged to form a social cognitive map. Accordingly, a complex adjacency matrix is developed, in which all the variables are formed in all the individual cognitive maps [25, 35]. One can use 2 strategic options development and analysis (SODA) approaches in his/her research topic to formulate cognitive social maps with soft operations:

1. The SODA I approach, which can be applied to integrate individual cognitive maps to help solve the problem using mathematical techniques on the edge weights and adjacency matrices.
2. Unlike the former one, the SODA II approach abandons individual cognitive maps and uses a group decision technology like Delphi to build cognitive maps directly with the help of the group.

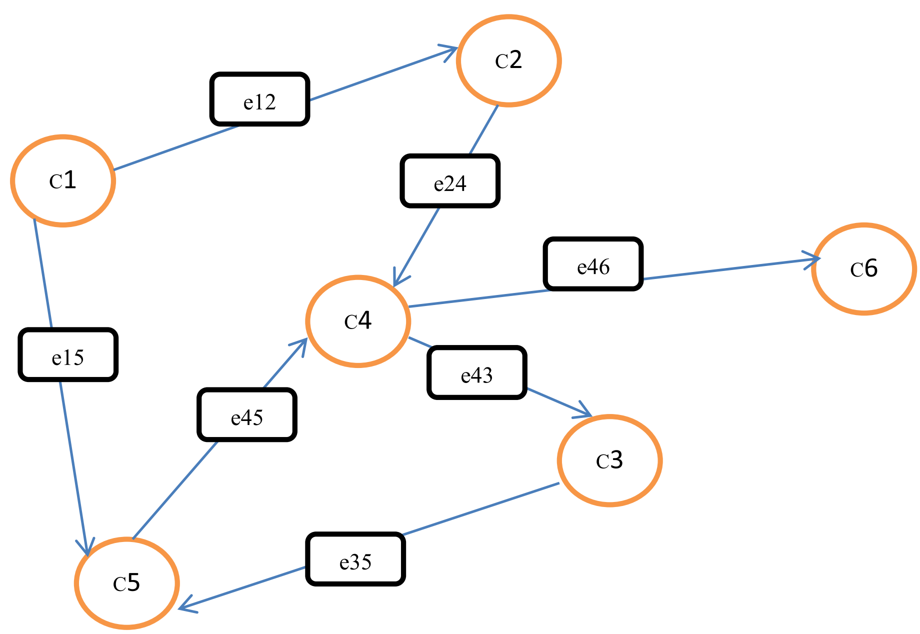

Fig. 1 A simple fuzzy cognitive map

The literature review [36] presented 2 methods for combining FCMs of different experts in the SODA I format:

- The 1st method was based on the expert credibility weight, according to which an estimate of the weights of the different experts' credits was first obtained to achieve the matrix of adjacency of the aggregated fuzzy cognitive map by weighting the adjacent matrices. The basis of this method was to calculate the Hamming distance between the inferences made by the different experts [37, 38].
- The 2nd method was based on averaging multiple FCMs [25, 31, 38]. This method was more common for combining FCMs of the different experts. In this method, adjacent matrices were added and then divided by the number of experts to obtain the weights ([39]).

Z-numbers

The concept of Z-number was intended to provide a basis for computation with numbers that were not reliable. Z-number was proposed by Zadeh [40] as a generalized version of the theory of uncertainty [41]. A Z-number is an ordered pair of fuzzy numbers denoted as $Z = (A, R)$. The 1st component, $\tilde{A}$, is a restriction on the values, indicating a real-valued uncertain variable, X. The 2nd component,R, is a measure of reliability for the 1st component. Z-numbers can be used to model uncertain information in the real-world. For example, in risk analysis, loss of the 5th component severity is very low, with the confidence state of 'very likely,' which can be written as a Z-number as follows: Z = very low, very likely

Research methodology

Future is a mental structure that can be shaped in accordance with an individual's perspective. It is necessary to use cognitive techniques and take into account the prominent role of the mind in the frameworks in order to implement an efficient foresight. Foresight is defined as selecting a preferable future among all the probable ones. The human mind intrinsically represents the world in the form of cognitive maps, which can be defined as what the mind perceives, adapts, and filters upon [42]. An individual's cognitive map demonstrates the contents of his/her mind. Conceptual maps and cognitive maps are two useful tools for depicting reason and wisdom. Cognitive maps are very beneficial for identifying critical issues and exploring future options by a group of experts [39].

The main focus of this article was to provide a method for the main stage of foresight, while the stages before and after that were mentioned generally. In this research, by presenting an expert-based model and using a combined method of cognitive mapping with the Z-number approach, a new qualitative method for foresight was presented. The reason for using Z-numbers was to cover the ambiguities in the experts' statements and increase reliability of the results. The research flowchart is shown in Fig. 2:

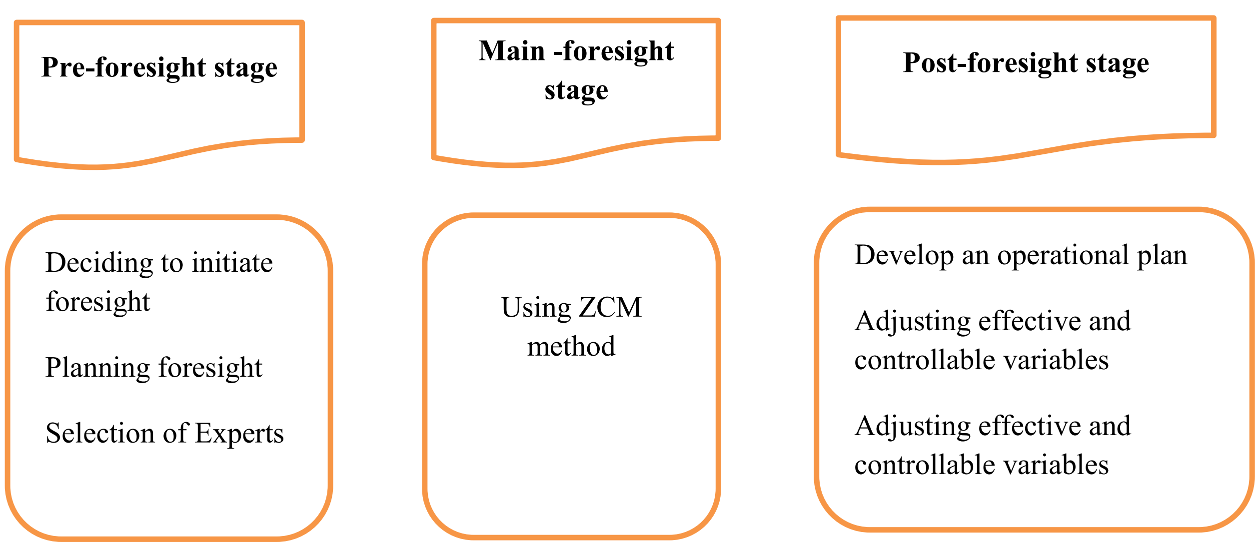

Fig. 2 Flowchart on the proposed method for foresight

Proposed framework for the cognitive-based foresight

The framework presented in the present paper used cognitive techniques to illustrate the experts' wisdom and facilitate the developments of perceptions in their minds, which were followed by achievement of intuition and identification of the probable future. Based on the models presented by Martin [14] and Horton [15], the framework was hierarchically divided into 3 phases: pre-foresight, the main stage of foresight, and post-foresight.

Pre-foresight stage

At this stage, the initial steps were taken and the necessary prerequisites for project implementation were provided. This stage, by itself, involved the following steps:

A) *Deciding to initiate foresight:* In this step, a high-level decision-making was needed to start the process based on a given topic as outlined in Martin's model (1995). This decision was essential on 2 different levels. On the one hand, foresight involved and necessitated vast resources and time and on the other hand, necessary authorities were given to the experts and stakeholders involved in the process.

B) *Planning foresight:* This step was also presented with different titles based on various models, such as those of Martin [14], Miles and Keenan [16], Saritas et al. [17], Santo et al. [18], and Reger [10]. This step dealt with foresight as a project, along with its various dimensions, including goals, horizons of vision, scope, focus, views, timing, budget, stakeholders, and the extents of participation identified and endorsed by the stakeholders.

C) *Selecting the experts:* Since the main focus of the proposed framework was on the experts' minds and various stages were involved for depicting their mentalities, selection of experts was of particular importance. Selection of the group of experts was to be done by the company's senior manager. The number and variety of experts could vary depending on the subject under study. The extent and scope of the subject of future research required a wider range of experts in terms of knowledge. The experts had to be selected in such a way that their visions of various fields were shaped into the subject of foresight, while intuition and insight about the probable future and preferable choices were made with higher reliability. It should be noted that the applicability and usefulness of cognitive maps were entirely dependent on the selection of appropriate experts and compilation of their cognitive maps. Also, the experts had to be selected from the different domains affecting the main subject, such as economic, political, social, and technological fields. Of course, the relevant texts and quantitative data could be used as a complement to the experts' knowledge.

The main foresight stage

As the core of implementation of a foresight project, the main stage has received particular attention in all the models reviewed in the literature. Foresight frameworks use a variety of commonly utilized techniques, including scenario planning, brainstorming, expert panel, and the Delphi method. In the proposed framework, a combination of Z-number and FCM was applied to resolve the uncertainties in the experts' opinions. This framework included the following steps (Fig. 3):

Step 1: Identifying variables affecting the subject This was the first and most crucial step in the foresight study, during which the variables, concepts, and factors affecting the subject matter were identified. These variables played the role of nodes in cognitive maps and could include an objective or subjective topic. The variables were identifiable through several approaches, including

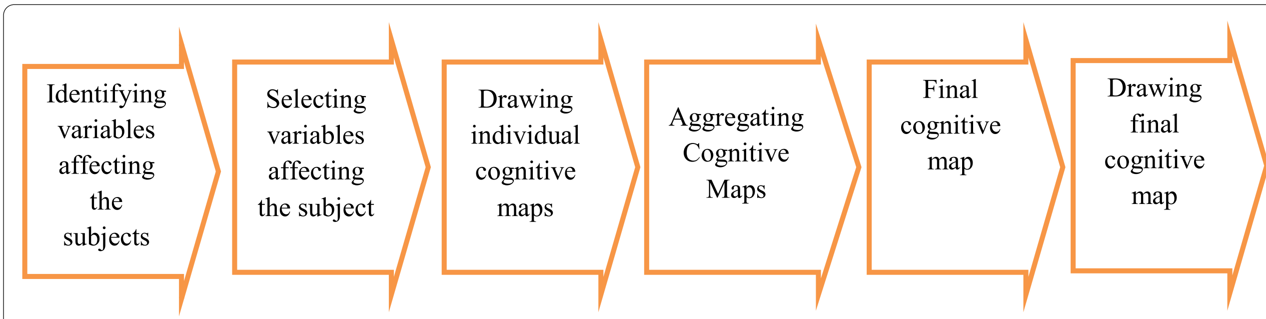

Fig. 3 Flowchart proposed method for main foresight stage

questionnaires, in-depth interviews, analysis of the written texts, quantitative data, and techniques of influence on the subconscious mind, along with the techniques adopted for strategic monitoring, such as Delphi meetings, expert panels, and environmental surveys [7]. The experts outlined their intended variables and expressed the significance of each one in the form of linguistic variables using the Z-number approach.

Step 2: Selecting variables affecting the subject Based on the variables identified in the previous step and taking into account the importance of each expert's opinions, the variables affecting the subject matter were selected.

Step 3: Drawing an individual cognitive map In this step, which involved asking a large number of the question of "what will happen if Variable X occurs" [43], a specific variable was considered and the effect of this variable/concept on the other variables was regarded using the experts' views and comments. This was repeated for all the variables identified in the previous step so as to determine the strengths or weights of the causal relationships between all the variables for each expert. Since the majority of worldly affairs are uncertain and ambiguous, there is no definite opinion on the relationship between the involved factors. Accordingly, using the concept of Z-number in the form of verbal variables, each expert explicated the relationship between the concepts from his/her perspective. In this case, the number of experts involved in the subject matter was a unique adjacency matrix as follows:

$$0 \leq e_{ij} \leq 1 \quad ; \quad i,j = 1,2,\ldots,n$$

$$Expert^k = E^k = \begin{bmatrix} e_{11}^k & \cdots & e_{1n}^k \\ \vdots & \ddots & \vdots \\ e_{n1}^k & \cdots & e_{nn}^k \end{bmatrix} \tag{1}$$

Step 4: Aggregating fuzzy cognitive maps In this stage, according to the individual adjacency matrices, each expert sought to aggregate the resulting cognitive maps. Accordingly, the weights of each expert's comments were used to obtain the averagely weighted method of the aggregated matrix. The resulting matrix indicated the relationship between the factors affecting the subject or the weights of edges in the cognitive maps.

Step 5: Determining the final fuzzy cognitive map Using the experts' wisdom, the researchers sought to eliminate the weak links between the variables. The minimum limit was defined by using the experts' collective wisdom. This minimum limit could be different among those of the different variables based on the obtained weights. If the weights of edges between the variables were below the minimum, the link would be considered weak and the matrix would be removed. As a suggested relationship for obtaining the minimum limit, we could use the rendering average of the difference between the highest and lowest values in the final adjacency matrix. The experts had to further identify the causal relationships. The (negative or positive) relationships between the variables were considered as a one-way cause-and-effect relation within the proposed framework.

Post-foresight stage

To complete the foresight process, after implementation of the proposed framework, we needed to enter the final phase, i.e., post-foresight phase, in which we were seeking to formulate an operational plan and achieve the preferable future agreed upon by the fuzzy cognitive map. Initially, the sequence of the variables in the map was specified for future achievement. The controllable and uncontrollable variables were separated based on the calculations carried out in the main foresight phase and then appropriate strategies and programs were determined for achieving the predetermined objectives and preferable future. The efficient programs were selected for implementation by the various available times and human and financial resources. The programs and policies were reviewed after implementation at certain time intervals. If the results turned out to be contrary to the predetermined policies, new programs were adopted and implemented. In the proposed framework, the relationship between each variable was assumed to be one-directional and determined through the experts' collective wisdom.

Case study

Information and communication technology (ICT) has become one of the most popular industries in the world in recent decades. Under the conditions governing this industry, one of the essential concerns of organizations is attraction of productive and scholarly human resources. Also, due to the existence of extensive job opportunities and expert knowledge, the "Staff Leave" rate is very high in this industry [44]. The costs that are imposed by "Staff Leave" and possible recruitments in the competing organizations are unthinkable. Hence, it is imperative that organizations try to reduce their employees' willingness to quit and maintain them by adopting appropriate human resource management strategies. In this section, to illustrate application of the proposed method, the problem of identifying and investigating the relationship between the factors affecting quitting of the staff members of an active company in the field of ICT will be discussed, the results of which can be used to formulate and adopt strategies with the possibility of more effectively planning to save the productive and scholarly human resources. In the first step, the proposed framework identified the effective variables on the topic of staff turnover in the ICT industry through individual interviews with the experts, brainstorming sessions, and the Delphi technique. According to the experts, 15 variables would affect the subject matter. The importance of each factor varied from the perspectives of the different experts, who expressed the significance of the variables and the degree of assurance of this statement by using 5 linguistic variables (Table 1). As an example, factor C_1 was of very high importance from the first expert's viewpoint and a statement was made with a high degree of confidence. By continuing this process, all the experts expressed their opinions as Z-numbers about the factors affecting the subject.

In the second step of the proposed framework, among the 15 factors identified in the first stage, the factors that had the highest score were selected as the main and effective factors on quitting of the ICT staff. Considering the linguistic variables as triangular fuzzy numbers, the calculations were simplified by converting the Z-numbers into crisp numbers and the importance of commenting by each expert (Table 2). The experts' opinions that were identified by the final decision maker were ranked as 0.2, 0.1, 0.2, 0.3, and 0.2 based on the order of importance, respectively. Using the mean weighting method, we selected the factors with the highest scores as the factors affecting the subject. After calculating such variables as age, level of education, organizational ownership, gender, salary, role ambiguity, job diversity, job satisfaction, job choice, bad boss, and justice in rewards, the factors affecting quitting of the ICT staff were selected. As an example, the first expert's comment on the first variable, which was referred to as a Z-number, was converted to a crisp number as follows:

High= H= (0.5, 0.75, 1)

$$X_{1,1} = \left({}^{1}\!/_{6}\,(0.75 + (4 \times 1) + 1) \right) \times \left({}^{1}\!/_{6}\,(0.5 + (4 \times 0.75) + 1) \right) = 0.718 \tag{2}$$

In the previous step, we selected 11 variables that had the most significant impacts on quitting of the staff members of the ICT industry by aggregating the experts' opinions. Now, the aim was to discover the causal relationships between the variables and draw the cognitive maps of each expert. For this purpose, each expert was considered individually by asking the question of "what will happen if Variable X occurs" following the discovery of the causal relationships of variable X with the other variables. Then, the number of the experts involved in the topic was entered into a matrix called the neighborhood matrix. There were 5 adjacent matrices in the present case study, in which the experts commented on how the relationships between the variables were determined based on the linguistic variables and the underlying approach. The comments of expert no. 1 on the causal

Table 1 Expert opinion about factors affecting ICT staff abandon based on Z-number

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}
Expert #1	(VH,H)	(H,M)	(L,H)	(M,H)	(VH,H)	(L,VH)	(VL,VH)	(H,L)	(VH,L)	(VL,H)	(M,L)	(H,H)	(VL,M)	(L,H)	(VH,VH)
Expert #2	(VH,M)	(H,VH)	(VH,M)	(L,VH)	(H,M)	(H,M)	(M,H)	(H,M)	(VH,M)	(L,H)	(VH,L)	(H,VH)	(VH,H)	(M,VH)	(VL,H)
Expert #3	(H,VH)	(VH,M)	(M,L)	(H,VH)	(H,M)	(M,L)	(L,M)	(VH,L)	(H,M)	(L,M)	(VH,M)	(L,H)	(H,M)	(H,M)	(H,M)
Expert #4	(M,H)	(M,H)	(H,H)	(H,L)	(M,VH)	(M,H)	(L,H)	(M,H)	(M,H)	(VH,L)	(H,L)	(M,H)	(VH,M)	(H,L)	(M,VH)
Expert #5	(H,M)	(M,L)	(M,VH)	(M,M)	(M,L)	(L,M)	(VL,M)	(L,VH)	(H,L)	(M,H)	(H,VH)	(VH,M)	(L,M)	(M,VH)	(L,VH)

Table 2 Experts commenting on the factors that affect the subject converted to a crisp number

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}
Expert #1	0.718	0.375	0.187	0.375	0.479	0.239	0.032	0.187	0.718	0.025	0.125	0.562	0.016	0.187	0.718
Expert #2	0.479	0.718	0.479	0.239	0.375	0.375	0.375	0.375	0.479	0.187	0.239	0.718	0.718	0.479	0.025
Expert #3	0.025	0.479	0.125	0.718	0.562	0.125	0.125	0.239	0.375	0.125	0.479	0.187	0.375	0.375	0.375
Expert #4	0.375	0.375	0.562	0.187	0.479	0.375	0.187	0.375	0.375	0.239	0.187	0.375	0.479	0.187	0.479
Expert #5	0.375	0.125	0.479	0.250	0.125	0.125	0.016	0.239	0.187	0.375	0.718	0.479	0.125	0.479	0.008
Score	0.325	0.425	0.360	0.388	0.412	0.236	0.156	0.288	0.392	0.2	0.385	0.427	0.378	0.36	0.287

Table 3 Adjacency matrix expert opinion number 1 in the form of Z-numbers

Expert 1	C_1	C_2	C_3	C_4	C_5	C_7	C_9	C_{11}	C_{12}	C_{13}	C_{14}
C_1	-	(VH,M)	(H,L)	(VH,M)	(M,H)	(L,M)	(L,M)	(VH,H)	(H,M)	(L,VH)	(VL,H)
C_2	-	-	(L,M)	(H,VH)	(M,H)	(H,VH)	(VL,M)	(VL,H)	(VH,H)	(H,H)	(L,H)
C_3	-	-	-	(VL,H)	(H,VH)	(M,H)	(L,H)	(VL,H)	(VL,M)	(M,M)	(H,M)
C_4	-	-	-	-	(VH,VH)	(M,L)	(VH,M)	(VL,H)	(M,H)	(L,H)	(H,H)
C_5	-	-	-	-	-	(M,L)	(M,L)	(M,H)	(H,VH)	(VH,H)	(VL,M)
C_7	-	-	-	-	-	-	(VL,M)	(VL,H)	(VH,H)	(H,M)	(H,H)
C_9	-	-	-	-	-	-	-	(M,H)	(L,H)	(H,VH)	(VH,VH)
C_{11}	-	-	-	-	-	-	-	-	(H,VH)	(VH,M)	(VH,L)
C_{12}	-	-	-	-	-	-	-	-	-	(H,M)	(VH,H)
C_{13}	-	-	-	-	-	-	-	-	-	-	(H,VH)
C_{14}	-	-	-	-	-	-	-	-	-	-	-

relationships between the variables are shown in Table 3 as an example. From this expert's viewpoint, with a moderate degree of confidence, variable C_1 had a very high correlation with variable C_2.

After identifying the cause-and-effect relations of the variables, the results of which were the developments of adjacency matrices to the number of experts, the final adjacency matrix was obtained by integrating and aggregating these matrices. Due to the computational complexity of the Z-number approach, a suitable approximation of the experts' opinions was initially obtained as a crisp number through Equation 6. The verbal variables used were triangular fuzzy numbers. Table 4 shows the adjacency matrix with crisp droplets. All the intersections in the adjacency matrix or the weights of edges in the model of fuzzy cognitive map were in the range of (0, 1) due to the approximation used to convert Z-numbers into crisp values. In this stage, all the elements of the adjacent matrix were converted to crisp numbers and the number of experts in the neighborhood matrix was achieved. As an example, the adjacency matrix converted to the crisp numbers related to expert no. 1 is presented in Table 4. The next part sought to integrate the fuzzy cognitive maps by using the adjacency matrices obtained with crisp elements in the previous step and considering the importance of each expert's opinions. Using the weighted average method, the adjacency matrix of the single weights was taken into account and the aggregate matrix was achieved. As an example, the equation used to calculate the relationship between the 1st and 2nd variables is shown below:

$$e_{12,\ \text{total}} = \frac{(w_1 \times e_{12,1}) + (w_2 \times e_{12,2}) + (w_3 \times e_{12,3}) + (w_4 \times e_{12,4}) + (w_5 \times e_{12,5})}{w_1 + w_2 + w_3 + w_4 + w_5} \tag{3}$$

In the 4th stage, using the experts' collective wisdom and taking into account a minimum limit, the weak links between the variables were not considered. The variables with a relationship value of lower than 0.4 were

Table 4 Adjacency matrix expert opinion number 1 converted to crisp numbers

Expert 1	C_1	C_2	C_3	C_4	C_5	C_7	C_9	C_{11}	C_{12}	C_{13}	C_{14}
C_1	-	0.479	0.187	0.479	0.375	0.125	0.125	0.718	0.375	0.239	0.025
C_2	-	-	0.125	0.718	0.375	0.718	0.016	0.025	0.718	0.562	0.187
C_3	-	-	-	0.025	0.718	0.375	0.187	0.025	0.016	0.25	0.375
C_4	-	-	-	-	0.918	0.125	0.479	0.025	0.375	0.187	0.016
C_5	-	-	-	-	-	0.125	0.125	0.375	0.718	0.718	0.016
C_7	-	-	-	-	-	-	0.016	0.025	0.718	0.375	0.562
C_9	-	-	-	-	-	-	-	0.375	0.187	0.718	0.918
C_{11}	-	-	-	-	-	-	-	-	0.918	0.479	0.239
C_{12}	-	-	-	-	-	-	-	-	-	0.375	0.718
C_{13}	-	-	-	-	-	-	-	-	-	-	0.718
C_{14}	-	-	-	-	-	-	-	-	-	-	-

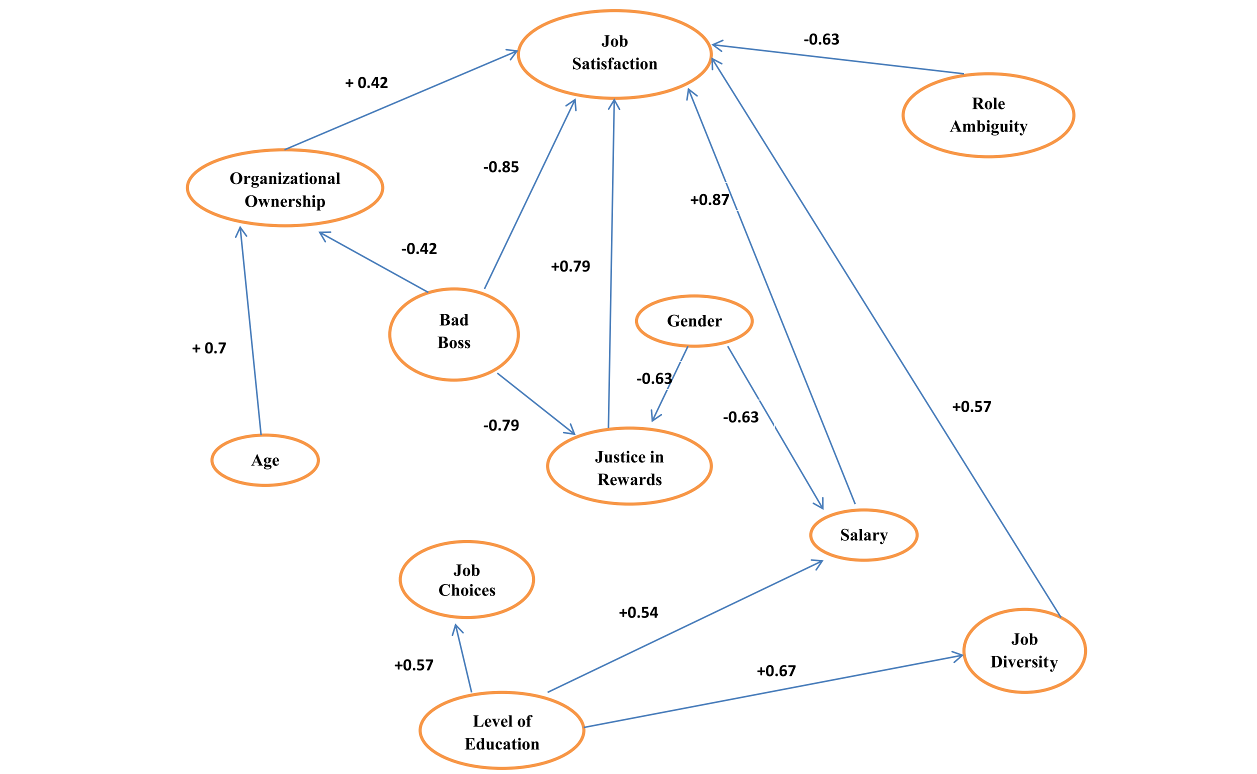

Fig. 4 Cognitive map of the factors affecting the ICT staff quitting

considered weak and thus removed from the adjacency matrix. Furthermore, the causal relationships between the variables, as well as the type of relationship that could be either direct or inverse, were determined using the experts' collective wisdom. In this way, the final matrix of the relationships between the variables and cognitive mapping of the problem of the ICT staff quitting was obtained (Fig. 4).

Discussion

In the proposed framework, each expert separately commented on the subject under study; therefore, the possibility that the experts affected one another was about zero. The role of a facilitator, which was responsible for collecting the data and information from the experts was of paramount importance in the proposed framework. The facilitator had to be able to reflect the comments objectively without any orientation in the interviews with the experts. Additionally, he had to play an effective role in the brainstorming sessions by using the Delphi method and other available techniques. 3, 5, 7, 9, and higher linguistic variables could be utilized to cover the uncertainty of commenting on the experts' opinions due to applying the Z-number approach and considering the nature of the subject; the more the experts' uncertainties toward the issue was, the higher the linguistic variables could be used to cover the uncertainties. The minimum limit in the proposed framework was considered to simplify the cognitive mapping. This minimum limit could take different numbers on different issues. The causal relationships between the variables could be either direct or inverse. A direct relationship meant that an increase or decrease in a variable would change the variables, with which the initial one was somehow associated in the same way. An inverse relationship indicated that an increase or decrease in a variable would cause an increase or decrease in the associated variables contrary to the first change. In the proposed framework, it was assumed that there was not a 2-way relationship between two variables and that there was only one direction of communication. Following the proposed framework of the experts involved in the subject, a comprehensive and shared understanding of the levels of causation between the variables involved in the subject was achieved and a range of scenarios and strategic options, which could be used to draw the perspective of probable and preferable futures emerged by interpreting the fuzzy cognitive mapping created. Since the practicality and usefulness of the proposed method were entirely dependent on the selection of appropriate experts and combination of their cognitive maps, lack of access to suitable experts and cooperation with them could be cited as limitations of the proposed model. The issues related to the reliability and validity of the mapping methods, as well as other qualitative research methods, are of great importance and researchers must ensure to represent proper concepts and mapping, as well as significant relationships and effects of their particular approaches. One of the best ways to validate cognitive mapping is to return it to the experts and get approval from them. Regarding the quality of the proposed framework, its validity had a strong dependence on the credibility of the experts involved in the subject and the more in-depth the experts' levels of knowledge were, the higher the model's credit rating was.

Conclusion

The present research was conducted to provide a framework for foresight using the Z-number concept and fuzzy cognitive map and overcome the uncertainty and ambiguity of issues. This study applied a qualitative method and the experts' opinions to identify the variables and factors affecting the main issue. Given the fact that most of the experts' comments are expressed as linguistic variables with a degree of ambiguity and uncertainty, the current research used a fuzzy cognitive map and Z-number approach to overcome this impreciseness. The proposed framework was applied to the main phase of foresight, namely, identification of variables and study of the causal relationships between them. Due to the nature of the foresight issues, the relevant contributing experts' comments were utilized, thus putting the proposed framework in the category of qualitative foresight methods. The proposed framework, in which the experts' ideas were expressed in the form of linguistic variables, could be used to deal with the issues of ambiguity and high uncertainty. The Z-number concept was applied to cover the ambiguity and uncertainty in the respondents' statements. Additionally, it was possible to use 3, 5, 7, 9, and more linguistic variables. Due to the qualitative nature of the proposed model, the framework validity was strongly dependent on the credibility of the experts involved in the subject; hence, efficient selection of experts related to the subject was of great significance. It was tried to enhance the model's credibility by assigning different weights to the various experts. Using a large number of experts increased the diversity of the final model, which would, in turn, augment the comprehensiveness of the final model. The combination of the proposed framework with decision-making models and its use for other issues that are in the domain of ambiguity and uncertainty can be recommended for future studies. In general, the proposed framework was applied to the issues, in which decision-making was based on the experts' opinions without the use of quantitative data. It was also applied to the issues, on which the experts had different opinions about the effective factors and could not reach a consensus regarding the involved variables. Based on the results of this case study, a comprehensive understanding of how the interacting variables would affect job quitting could be achieved. Therefore, the feasibility of adopting and designing the strategies for maintaining the technical staff in the organization would be facilitated by the resulting model. Through this approach, organizational strategists can have a complete picture of the effects of job quitting factors on the technical staff in the ICT industry and predict the impacts of making changes to each of the mentioned variables under a new strategy.

Appendix

Some concepts and definitions

In this section, the concepts of the selected fuzzy membership function and the graded mean integration representation (GMIR), which are used in this study, are explained.

The choice of the fuzzy membership function

A fuzzy set A is defined on a universe X as presented below:

$$A = \{\langle x; \mu A\ (x)\rangle\ |x \in X\} \tag{3}$$

Where μ_A: $X \rightarrow [0; 1]$ is the membership function A. The membership value $\mu_A\ (x)$ describes the degree of belongingness of $x \in X$ in A [30].

In a real case, experts may give their opinions by fuzzy numbers. For instance, in a new product price estimation, one expert may give his opinion as the minimum price is 5 dollars, the possible price of the product maybe 6 dollars, and the maximum price of this product will not exceed 7 dollars. So, we can use a triangular fuzzy number [20, 26, 45] to show the expert's opinion. A triangular fuzzy number $\tilde{A}$ can be determined by a triplet (a_1, a_2, a_3), where the membership can be determined as the following equation, which is also shown in Fig. 5.

$$\mu_{\tilde{A}}(x) = \begin{cases} 0, & x \in (-\infty, a_1) \\ \frac{x-a_1}{a_2-a_1}, & x \in [a_1, a_2] \\ \frac{c-x}{a_3-a_2}, & x \in [a_2, a_3] \\ 0, & x \in (a_3, +\infty) \end{cases} \tag{4}$$

Let X be the universe of discourse, which includes five linguistic variables describing the degree of security, $X = \{$Very Low; Low; Medium; High; Very High$\}$, presuming that only two adjoining linguistic variables have the overlap of meanings [46]. Moreover, let $\tilde{A}$ be a fuzzy set of the universe of discourse X subjectively defined as follow:

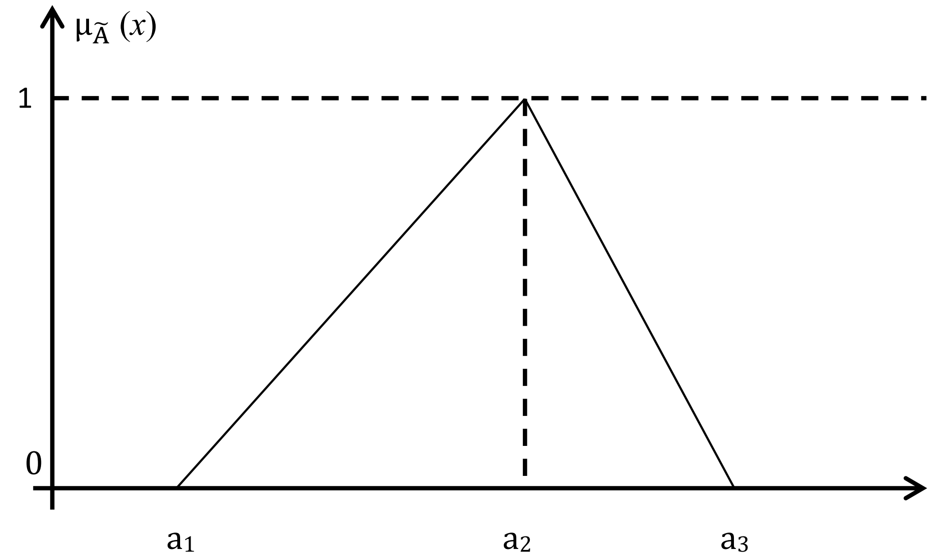

Fig. 5 Triangular fuzzy number

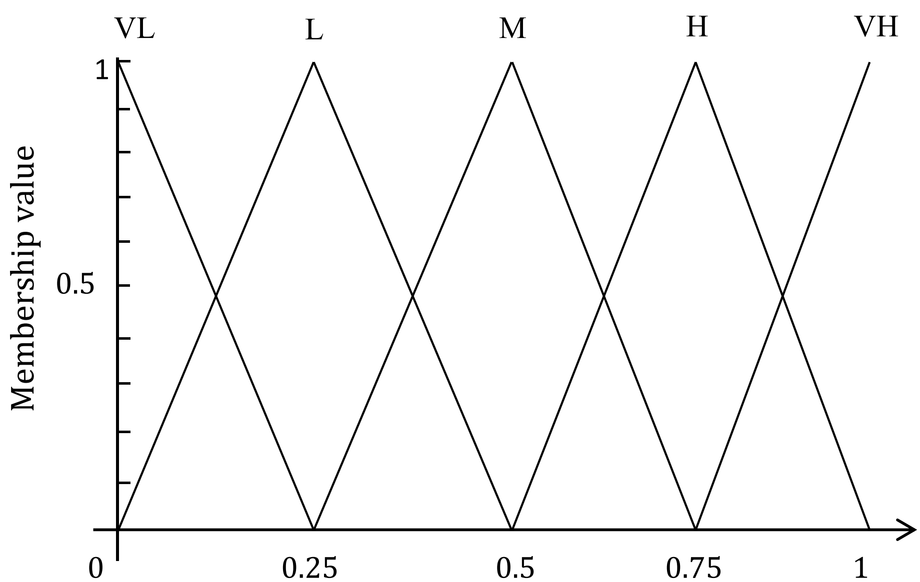

Fig. 6 Membership function of criteria

$$
\begin{aligned}
f_{Very\ Low}(x) &= -4x + 1, \quad 0 \le x \le 0.25 \\
f_{Low}(x) &= \begin{cases} 4x, & 0 \le x \le 0.25 \\ -4x + 2, & 0.25 \le x \le 0.5 \end{cases} \\
f_{Medium}(x) &= \begin{cases} 4x - 1, & 0.25 \le x \le 0.5 \\ -4x + 3, & 0.5 \le x \le 0.75 \end{cases} \\
f_{High}(x) &= \begin{cases} 4x - 2, & 0.5 \le x \le 0.75 \\ -4x + 4, & 0.75 \le x \le 1 \end{cases} \\
f_{Very\ High}(x) &= 4x - 3, \quad 0.75 \le x \le 1
\end{aligned}
\tag{5}
$$

Where *fVery Low*; *fLow*; *fMedium*; *fHigh*; and *fVery High* are the membership functions of the fuzzy sets, which are shown in Fig. 6 and 7.

The graded mean integration representation (GMIR)

Let $\tilde{A} = (a_1,a_2,a_3)$ and $\tilde{R} = (b_1,b_2,b_3)$ be two triangular fuzzy numbers (see Fig. 7). The graded mean integration

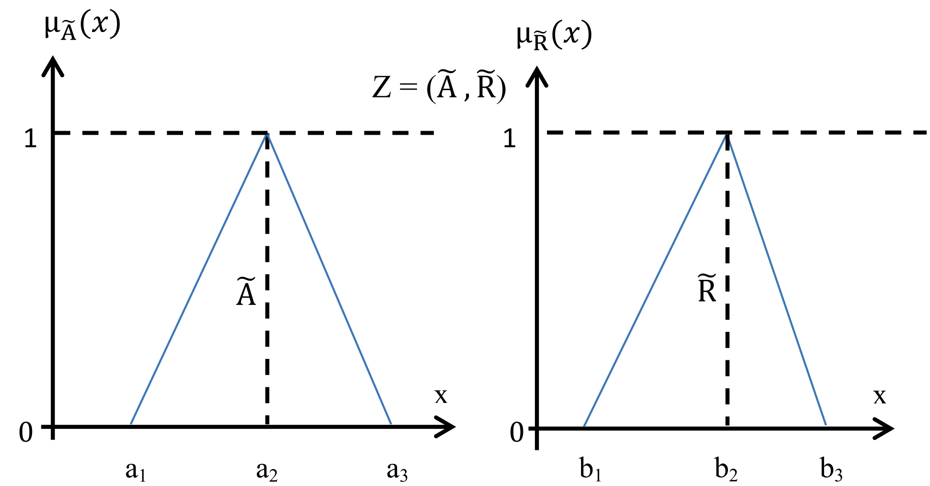

Fig. 7 A simple Z-number

representation of triangular fuzzy number $\tilde{A}$ and $\tilde{R}$ can be obtained as follows:

$$P\left(\tilde{A}\right) = \frac{1}{6}\left(a_1 + 4 \times a_2 + a_3\right) \tag{6}$$

$$P\left(\tilde{R}\right) = \frac{1}{6}\left(b_1 + 4 \times b_2 + b_3\right) \tag{7}$$

Multiplication on triangular fuzzy numbers

The canonical representation of operation on triangular fuzzy numbers, which are based on the graded mean integration representation method [45] is used to obtain the weight of each criterion. The canonical representation of the multiplication operation on triangular fuzzy numbers $\tilde{A}$ and $\tilde{R}$ can be defined as:

$$P\left(\tilde{A} * \tilde{R}\right) = P\left(\tilde{A}\right) \times P\left(\tilde{R}\right) = \frac{1}{6}\left(a_1 + 4 \times a_2 + a_3\right) \times \frac{1}{6}\left(b_1 + 4 \times b_2 + b_3\right) \tag{8}$$

Authors' contributions

Mostafa Izadi: Conceptualization, methodology, writing—original draft, review and editing; HamidReza Seiti: Supervision, review, and editing; Mostafa Jafarian: Review and editing. The authors read and approved the final manuscript.

Declarations

Competing interests

The authors declare that they have no competing interests.

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