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RESEARCH PAPER

Designing a Mamdani Fuzzy Inference Expert System for evaluating Human Resources in the Iranian Construction Industry

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Abstract
The importance of human resources is an inescapable issue that lack of proper management will reduce productivity in project-based organizations. human resources assessment is one of the complex processes in organizations that require explicit analysis by strategic, key, and operational jobs in order to periodically monitor, recruit and hire it according to the organizational position of employees. In recent years, various models for measuring human resources in project-based organizations have been proposed, but the important issue is to provide an expert system that can provide results with high reliability. To this end, the fuzzy inference system is felt like a response to this need. Due to the identified study gap, the present study seeks to design an expert system consistent with Mamdani fuzzy inference to measure manpower in a project-based organization in Iran. This system shows the final status of human resource assessment in the Iranian project-oriented organization and the status of each of its main dimensions. In order to show the potential and practical benefits of this system was implemented in a case study. Finally, by analyzing the system outputs, the optimal performance of the designed system is analyzed and finalized with the relevant information of the organization.

Keywords: Human Resources, Project-Based Organization, Uncertainty, Expert System, Mamdani Fuzzy Inference.

1. Introduction

In today's competitive world, one of the important elements for creating change, for the survival of the organization, and achieving its goals and missions is human. What gives life to the category of transformation and ensures the survival of the organization is human resources because the role of man in the organization and the way of looking at him will significantly contribute to the success or failure of the organization (Diaz Carrion et al., 2021). With the onset of the third millennium, the role of human resources in projects and organizations is becoming more vivid and is assumed as the only factor for success and sustainable competitive advantage in organizations. This is especially true in today's knowledge economy (Bloom & Reenen, 2011). A review of researches conducted in recent years shows that effective human resource management is a key factor in the success of organizations (Greer,

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2021) as human resource management involves programs specifically related to human beings in organizations and creating facilities for their effective use in achieving individual and organizational goals (Christiana & Mahalakshmi, 2012). Therefore, human resource management in general means the management of a strategic resource called organizational people that organizations can gain a competitive advantage through the proper management of this strategic resource and create more added value than other competitors (Asfahani, 2021). In this regard, trying to measure the impact of human resources on company performance was the first step that affected the traditional intellectual structure of human resources, considered merely a professional administrative unit (Moghaddam et al., 2021). Becker et al. (1996) argues that the most effective action that human resource managers can take to ensure strategic human resource participation is to establish a measurement system that acceptably reflects the impact of human resources on business performance. To design such a measurement system, human resources managers must adopt a completely different perspective, through which they understand how human resources play a key role in implementing an organization's strategy. In fact, by creating a good strategic architecture for human resources, managers across the organization understand exactly how people create value and how the value creation process can be measured (Armstrong, 2011).

To this end, in recent decades, many studies have examined the relationship between human resource management, productivity, and the performance of project-based organizations (Bloom and Reenen, 2011; McDowall and Saunders, 2010; Pirzada et al., 2013; Cania, 2014). However, what is crucial and remains an ambiguity is that researches have not designed an effective and efficient system for strong human resource management that can measure human resources by its results in project-based organizations. For example, Collins (2021) developed a model for strategic human resource management and showed that recognizing the factors related to social capital, human capital, and management will lead to effective management and competitive advantage in project-based organizations. Also, in another study, Abbaspour and Dabirian (2020) assumed the importance of human resource development as one of the key parts in human resource management and used the system dynamics method to recognize the effective factors for better management of human resources. Examining the results, it was found that the implementation of financial incentive payment policy and improving the skills of workforce through training have been effective in increasing the productivity of the project-based organization. Finally, using the model presented by the researchers, they examined the effects of applying human resource development policies on project performance in terms of time and made the necessary planning to develop human resources for construction projects and improve human resource productivity and project performance. Susilowati et al. (2021) developed effective models of human resource management in Indonesian construction companies and demonstrated that human resource management in Indonesian construction companies is in good or excellent condition, showing that most of the industry has implemented management policies. However, the human resource planning model in the Indonesian construction company is more focused on operational planning, i.e., this planning for construction companies in Indonesia is still project-based or short-term.

A review of researches conducted in recent years shows that although various models and frameworks have been proposed for human resource measurement in project-based organizations, the important issue in human resource measurement is the provision of an expert system so that the results can be presented with high reliability and accuracy and implemented in large project-based organizations. To this end, the fuzzy inference system is felt to be a response to this need. Thus, assuming the study gap identified by researchers, a fuzzy inference system has been used to measure human resources in the construction

industry. The reason for using the fuzzy inference system is subjective judgments, the use of linguistic variables in most criteria for measuring human resources, and the intelligence of the desired method. Intelligence means behaving like a human being and observing all the rules defined for it at the same time, and this is what human beings use continuously in their daily activities. The inputs of the fuzzy inference system involve the importance measurement of decision-making criteria, used to determine the importance of each criterion by the fuzzy analytical hierarchy process (Chang method). The system then takes the inputs and the output delivers the human resource measurement via performing a series of actions on them and written rules. In this regard, the most important innovation and significant contribution of the study are summarized as follows:

1. Providing a model based on expert systems to increase the efficiency of human resources in a project-based organization
2. Improving the quality of project implementation in project-based organizations and effective and efficient use of human resources in the organization
3. Using expert systems in various activities and projects in project-based organizations to change traditional views in this field.
4. Simultaneous consideration of two approaches to productivity and the use of expert system, which can be considered novel research with qualified conditions for implementation; the loss of human resources in the management of different parts of the country is especially a critical challenge ahead in the development of the country and is clear taking the importance of this research into account.

The rest of the article is organized as follows. In the second section, Theories, elements, and consequences of human resources evaluation are discussed. The methodology of the study is presented in the third section, and the stages of the study are presented in the fourth section, and in the fifth section, the implementation of the expert system is presented in a case study in one of the most important project-based organizations in Iran. Finally, the discussion and conclusion are presented in the fifth and sixth sections.

2. Theories, elements, and consequences of human resources evaluation

To understand human resource evaluation, it is better to first understand the concept of human resources and then its management. Human resource is the most important factor influencing any business. Increasing labor productivity in any sector can increase economic productivity and ultimately promote the economic growth of companies and organizations. Since the employees of organizations are known as a source of competitive advantage, human resource management can be mentioned as a tool that organizations can use this tool to reduce the problems that these companies face. It is encountered, used (Rao & Teegen, 2009). In this regard, trying to measure the impact of human resources on company performance was the first step that affected the traditional intellectual structure of human resources, which was considered only a professional administrative unit (Moghaddam et al., 2021). Becker (1996) argues that the most effective action that human resource managers can take to ensure strategic human resource participation is to establish a measurement system that acceptable reflects the impact of human resources on business performance. To design such a measurement system, human resource managers must adopt a completely different perspective. The perspective through which they understand how human resources play a key role in implementing the organization's strategy. In fact, by creating a good strategic architecture for human resources, managers across the organization understand exactly how people create value and how the value creation process can be measured. Human resource evaluation means evaluating the quality of organizational human resource activities and their

success rate in supporting the organization's strategy (Asfahani, 2021). In this section, a set of methods, indicators and variables that have been used so far to evaluate human resource management is presented. The aim is to get acquainted with the set of indicators that have been used in this regard so far. Based on this, it is examined to what extent these experiences can be used to evaluate the effectiveness and efficiency of the four human resource management plans. Regarding human resource evaluation methods, it should be noted that despite the various efforts that have been made in this regard, still (Armstrong, 2011):

1. Human resources (compared to units such as finance, production and marketing) lack appropriate measurement indicators and analysis models.

2. Human resources lack analytical models that show the relationship between human resource activities and the effectiveness of the organization.

Many methods and models have been proposed to evaluate issues related to human resources. These methods can be divided into two groups:

1) Methods and models that evaluate the performance of "human resource", including the requirements of the ISO standard, the individual ranking model and the 360-feedback model, etc.

2) Methods and models that evaluate the performance of the "human resource management system", which includes a Balanced Scorecard (BSC), European Foundation for Quality Management (EFQM), and etc.

The importance of the issue was fully explained in the light of the material described on human resource evaluation, its theories and implications. We will now evaluate human resources in the Iranian manufacturing industry by focusing on its challenges in specific areas.

2.1. Evaluating Human Resources in the Iranian Construction Industry with focus on its challenges

Every year, a large amount of the country's budget is allocated to construction projects that proper management of these projects in terms of human resources involved in the work can increase productivity. What gives life to change and ensures the survival of the organization is human resources. The role of human resources in projects and organizations is becoming more and more prominent, and it is now mentioned as the only factor in achieving success and sustainable competitive advantage in the organization. This is especially true in today's knowledge economy (Loosemore et al. 2003). However, human resource management in organizations faces many challenges, including globalization, shortage of skilled and committed workforce, decision-making pyramid, lack of understanding of employee needs, lack of planning, inadequacy, discrimination, interest. Insufficient side of human resources, lack of motivation, lack of employee participation, leaving the cooperation of employees with the history of the organization, etc. In the meantime, it is the duty of human resource managers to address these challenges or prevent most of them from occurring by empowering their employees (Dainty& Loosemore, 2013). Human resource management is the process of working with people so that they and their organization are fully empowered, even when change requires new skills, new responsibilities, and new forms of relationships. In fact, human resource management is the use of human resources for the goals of the organization and includes activities such as recruitment and recruitment, training, payroll and organizational relationships. In other words, human resource management is a function in the organization that maximizes the performance of employees in serving the strategic goals of the employer. Human resource management seeks to find how people are managed in organizations, focusing on policies and systems (Samimi & Sydow, 2021). Human resource management units and departments are particularly responsible for a number of activities,

including recruitment, training and development, performance appraisal, and rewards (for example, payroll and benefits system management). Human resource management also pays attention to industrial relations, which is the balance of organizational actions with the rules resulting from discussions between employees and managers and government laws. With these interpretations, the role of human resources in achieving companies active in the construction industry is a pivotal and effective role. Without considering the needs and different conditions of human resources, these companies and especially the construction industry cannot achieve their business goals (Abbasi & Khalil Zadeh, 2021).

2.2. Evaluating Human Resources in the industry: a review of past studies

In this section, we review the studies conducted in recent decades on the issue of human resource evaluation in the construction industry. For example, Rajabi Jafarabad et al. (2019) in their article entitled "Human Resource Management in the Construction Industry" examines the challenges of human resources in the construction industry and offers solutions to improve this area. Researchers used qualitative-descriptive research methods based on library studies and the use of books and articles. These results suggest that human resource factors in the construction industry include setting formal goals, determining appropriate strategies, and searching for creative manpower in projects. Human resource development also reflects the growth and development of the human resource management cycle in the field of job management and performance, which ensures that people working on projects can fill job gaps and advance the construction industry. In another study, Yarahmadi et al. (2016) in their article entitled "Modelling human resource productivity in the urban construction industry by providing a qualitative model HR.PS" using the fuzzy method of performance status data Human resources in construction contractors were analyzed. The studied factors were prioritized in descending fuzzy numbers in the above 4 categories, then in the form of the second questionnaire were given to 3 contracting companies with ranks 1, 2, and 3 in the field of construction. After the analysis, the results were presented as a "qualitative model of human resource productivity" which represents the quality status of the productivity of each contracting company, which in the continuation of the research, their productivity has been compared with each other. Memarian (2014) in his article entitled "Targeting human resource management in construction projects and mass construction of cities" has targeted the management of human resources in the construction industry. The research method is a library study form and a questionnaire for surveying first-grade managers and research conducted in this field. The results of this study show the effect of increasing the use of correct human resource techniques based on the performance of construction projects and the construction industry and mass production of cities. Ziaei Nafchi et al. (2021) Stated that the emergence of the fourth industrial revolution has led to an entirely fresh approach to production, helping to enhance the key industrial processes and therefore increase the growth of labor productivity and competitiveness. Simultaneously, evaluation of the human resource compels changes in the organization of work. The article intends to construct a model for predicting the allocation of human resources in the sectors of the national economy of the Czech Republic. The model used in this research visualizes the shift of labor in the economic sectors of the Czech Republic from the year 2013 to the following years soon. The main contribution of this article is to show the growth of employment in the high-tech services sector, which will have an ascending trend. Welmilla (2021) in a study entitled "Human resources challenges in the apparel industry in Sri Lanka" identified the human resource challenges in the Sri Lankan apparel sector and provided recommendations for safety by managing barriers to promote future sustainability in the industry. The research approach is qualitative and followed the case study method. Face-to-face interviews were the method of

collecting data by following a semi-structured questionnaire for the research, and the data analysis method was the thematic analysis. The finding demonstrates nine core human resources challenges in the industry in Sri Lanka. Also on the other hand, Farshad et al. (2020) assessed the factors affecting the improvement of human resources. They revealed that the professional behavior of citizens (individual characteristics, social responsibility, and behavior in society), job performance (professional performance, organizational performance, and research performance), and innovation (individual, organizational, and social) are the important effective factors affecting the improvement of human resource measurement, which are the basis for the production and provision of services in organizations and one of the basic strategies in increasing efficiency and productivity. Outman et al. (2018) provided a framework for examining effective human resource management in the construction industry. The results of the research led to the identification of 11 indicators in the field of improving human resource management. These indicators, after survey and weighting, include designing and decision-making, benefiting from a ready and fresh workforce, law enforcement, employee behavior, inter-employee communications, effective employee management, employee training, having specialized knowledge, staff empowerment, and development of instructions, respectively. Mila and Soodi (2021) presented a model to evaluate human resource improvement programs in the organization. They identified factors affecting the measurement of human resources in the organization. Estiri et al. (2020) provided a framework for identifying factors influencing the measurement of human resources that lead to improved performance of the project-based organization and revealed that the framework can be used to improve employee performance and thus the performance of the organization. Accordingly, given the limited resources of organizations, the priorities presented can be useful in budgeting projects to improve human resource management and allocate appropriate resources.

3. Research methodology

3.1. Introduction of fuzzy analytical hierarchy process (Chang method)

The concept of fuzziness has been considered indirectly in classical hierarchical analysis without the use of fuzzy sets. In fact, in this method, fuzziness is involved in determining the pairwise comparison matrices using verbal expressions. Therefore, by generalizing the above method, some methods are presented in which fuzzy numbers are used to express the preference of elements. Among these are the methods presented by Buckley (1985), Larhon and Badrich (1983), and Chang (1992). An extensive study of these techniques can also be found in the work of Karaman (2004) (Buckley, 1985; Buckley et al., 2001). Since Chang's fuzzy analytical hierarchy process is used in this research, the following steps explain the implementation steps of the method (Chang, 1996):

Step 1: First, the priority of experts is specified relative to each other. Chang method is used for this purpose. In Relationships (1) and (2), G represents the list of experts from number 1 to n, and M represents the degree of preference of experts over each other. $M_{gi}^{J}\ (j=1,2,\ldots,m)$ and all values are fuzzy that are used in the model:

$$G=\{g_1,g_2,g_3,\ldots,g_n\} \tag{1}$$

$$M_{gi}^{1},M_{gi}^{2},\ldots,M_{gi}^{m} \tag{2}$$

Step 2: First, using the fuzzy addition function, the sum of each row of the pairwise comparison matrix is obtained (i.e., for each expert). This step is done using Equation (3):

$$\sum_{j=1}^{m} M_{gi}^{J} = (\sum_{j=1}^{m} l_l, \sum_{j=1}^{m} m_l, \sum_{j=1}^{m} u_l) \quad (3)$$

Step 3: All fuzzy numbers from the previous operation are summed up. In this way, the sum of all fuzzy numbers is obtained from the pairwise comparison table of experts.

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{l} = (\sum_{j=1}^{n} l_l, \sum_{j=1}^{n} m_l, \sum_{j=1}^{n} u_l) \quad (4)$$

Step 4: The inverse value of the vector obtained in step 3 is calculated through Equation (5).

$$[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{J}]^{-1} = \left[\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right] \quad (5)$$

Step 5: The fuzzy value obtained by adding the rows (first step) is multiplied by the value obtained in the third step.

$$S_{\mathrm{i}} = \sum_{\mathrm{j=1}}^{\mathrm{m}} \mathrm{M}_{\mathrm{gi}}^{\mathrm{j}} \mathrm{V}\left[\sum_{\mathrm{i=1}}^{\mathrm{n}}\sum_{\mathrm{j=1}}^{\mathrm{m}} \mathrm{M}_{\mathrm{gi}}^{\mathrm{j}}\right]^{-1} \quad (6)$$

In this way, the fuzzy weight vector of each criterion is obtained (Chang, 1992). The weight obtained is used when determining the results of expert system rules. The fuzzy linguistic values used in this study to weight the expert opinion are presented in Table 1:

Table 1. Linguistic terms for weighting experts

Linguistic terms	Fuzzy numbers
Quite strong	(7.2, 4, 9.2)
Very strong	(5.2, 3, 7.2)
Almost strong	(3.2, 2, 5.2)
Weak	(2.3, 1, 3.2)
Equal	(1, 1, 1)
Weak	(2.3, 1, 3.2)
Almost strong	(2.3, 1, 2.3)
Very strong	(2.7, 1.3, 2.5)
Quite strong	(2.9, 1.4, 2.7)

3.2. Fuzzy expert system according to Mamdani fuzzy inference system

Fuzzy inference system provides a systematic process for converting a knowledge base into a nonlinear mapping. So, knowledge-based systems (fuzzy systems) are used in engineering and decision-making. Mamdani and Asilian used a fuzzy inference system in 1975 to control the combination of a steam engine and a boiler using a combination of linguistic control rules in the experiments of human operators. In 1978, Holmblad and Ostergaard used the first fuzzy controller to control a complete industrial process, i.e., the cement kiln. Since then, fuzzy controllers have been used in many industrial devices and processes, such as subways, robotics, and many other decision-making issues. A fuzzy system has the following components (Ahmadi et al., 2020):

1. A fuzzifier at the input that converts the numeric value of variables into a fuzzy set
2. The base of fuzzy rules that consists of a set of if-then rules
3. Fuzzy inference engine that converts inputs to output with a series of operations
4. Defuzzifier that converts fuzzy output to a crisp value. Figure 1 shows the steps of a fuzzy inference system.

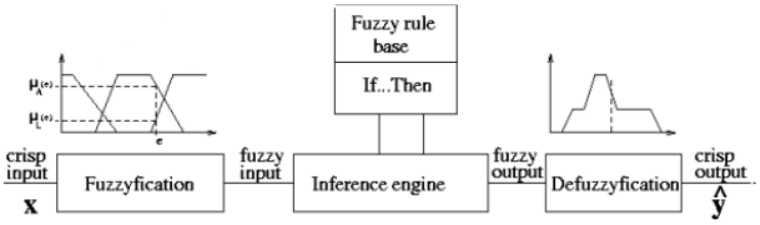

Figure 1. Steps of a Mamdani fuzzy inference system (Foong, 2010)

3.2.1. Fuzzification

In this step, for each input variable, membership functions are considered so that the crisp inputs are converted to fuzzy and placed in the fuzzy inference system. There are different types of membership functions such as triangular, trapezoidal, Gaussian, etc. In the present study, the triangular membership function has been used.

3.2.2. Explaining the rules of fuzzy expert system

The inference center of an expert system consists of a set of if-then rules. In a fuzzy expert system, rules are expressed by a set of verbal expressions. The rules of the fuzzy expert system evaluate the desired status with the status of the item under consideration and the degree of conformity of the desired status with the status of the studied item with linguistic expression.

3.2.3. Fuzzy inference engine

The fuzzy inference engine operator is like the human reasoning process. The output is determined by applying it to the inputs and rules, and this is what man does in many of his judgments. The performance of the fuzzy inference engine can be divided into four parts:

1. Applying input to premises and obtaining their membership rank
This part cannot be considered a function of fuzzy inference engine, but to better understand the performance of fuzzy inference engine, this part is included in the operation of fuzzy inference engine. Figure 2 shows the application of input to the premise and the degree of membership.

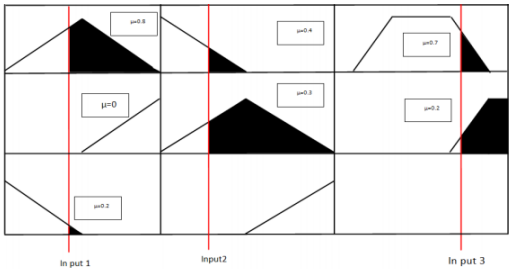

Figure 2. The degree of membership of each function

2. Application of fuzzy operators
When the number of premises exceeds one, fuzzy operators must be used to obtain a number that represents the product of the premises over that rule, and then that number is used in the output function. This number is called the "truth number" of that rule. One of the most

important relationships in this section is the Mamdani–Larsen's implication. Mamdani–Larsen's implication uses the min and multiplication operators for the truth number of each rule. Formulas (7) and (8) show the Mamdani and Larsen's implications, respectively:

$$R(u,v)=\min\left(\mu_{\tilde{A}}(u),\mu_{\tilde{B}}(v)\right) \quad (7)$$

$$R(u,v)=\mu_{\tilde{A}}(u).\mu_{\tilde{B}}(v) \quad (8)$$

To obtain the truth number of each rule, Mamdani implication has been used.

3. Applying the implication method

Implication method is the application of the truth number to the output function. The input of the implication number indicates the truth number, and its output is a fuzzy set of output. Before applying the implication method, the weight of each rule determined by the expert or any method must be multiplied by the truth number and then applied to the output function. Applying that number means slicing the output function in that number.

4. Aggregation of outputs

Since decision-making is based on all the rules in fuzzy inference systems, the rules must be combined in a way to make a decision. Aggregation is the method by which all the output sets of each rule are combined into a single fuzzy set. The aggregation process input is a list of output functions sliced by the implication process for each rule, and its output is a fuzzy set for the output. There are different methods for aggregation, the most important of which is maximization and addition which are used in the present study.

3.2.4. Defuzzification

Defuzzification is a process of turning a fuzzy set into a crisp number. Therefore, the input of the defuzzification process is a fuzzy set and the output is a number. Fuzzification contributes to mid-stage valuation, and the final output of interest for each variable is only one number. There are different methods such as center of gravity, bisector, half maximum, and the largest maximum and smallest maximum for defuzzification, but the center of gravity method is the most common method. Its value is calculated from Equation (9):

$$Z^{*}=\frac{\int \mu_{A}(z).z\,dz}{\int \mu_{A}(z).dz} \quad (9)$$

1. Execution steps of designing fuzzy expert system in accordance with Mamdani fuzzy inference system

Figure 3 illustrates the schematic diagram of the research implementation process based on the cases described in an overview, and in the following, the implementation steps of designing a fuzzy expert system in accordance with Mamdani fuzzy inference system are described.

Step 1: Determining the appropriate criteria

By reviewing articles and studies in the field of human resource productivity, productivity criteria for obtaining jobs are extracted. In addition, the criteria that have been used in the organization to evaluate employees are added to the list of criteria.

Step 2: Determining the weights of human resource productivity criteria with Chang's fuzzy technique

The researcher determines an expert group in the form of a questionnaire to confirm and validate the effective criteria identified in the first step. If the criterion is not approved, that criterion will be removed from the list of criteria for determining the productivity of

employees after the consensus of experts, or the experts will take action to modify the criteria. The selected criteria are then evaluated by Chang's fuzzy technique.

Step 3: Determining the structure of the fuzzy expert system

By holding in-depth interviews and brainstorming sessions for all selected qualitative criteria, the relevant verbal variables are determined, and for quantitative criteria, specific ranges are considered that are used in fuzzification of inputs. Afterwards, the fuzzy ranges of all criteria are determined and finally their membership functions are defined. Another important component of the fuzzy expert system is the knowledge base of the system, which is formed at this stage so that knowledge engineering must be done. Through holding in-depth interviews and numerous brainstorming sessions, the knowledge and experiences of experts are extracted, their mental models are structured, and the rules of the expert system are created.

Step 4: Determining the value for the criteria

A group of experts are selected by the senior management of the organization, which may be different from the previous group due to the scope of the organization activity, to value the criteria approved in the previous step by fully evaluating the criteria. After valuation of the criteria by experts, the verbal values are converted into fuzzy numbers and the decision matrix is formed, and then the average of their comments is calculated and its unit value is determined for each criterion, and in fact the fuzzy operation is over.

Step 5: Assessing human resources through a fuzzy expert system consistent with Mamdani fuzzy inference

According to the values set for each criterion in the previous step and the formation of the knowledge base of the fuzzy expert system, fuzzy inference operations are performed and the desired output is obtained in this case in the fuzzy expert system using the Mamdani method. After the defuzzification operation, the rank of each human resource is determined. The expert system is designed based on the weights set for the criteria and the ideal score obtained separately for strategic, operational, and support jobs in MATLAB.

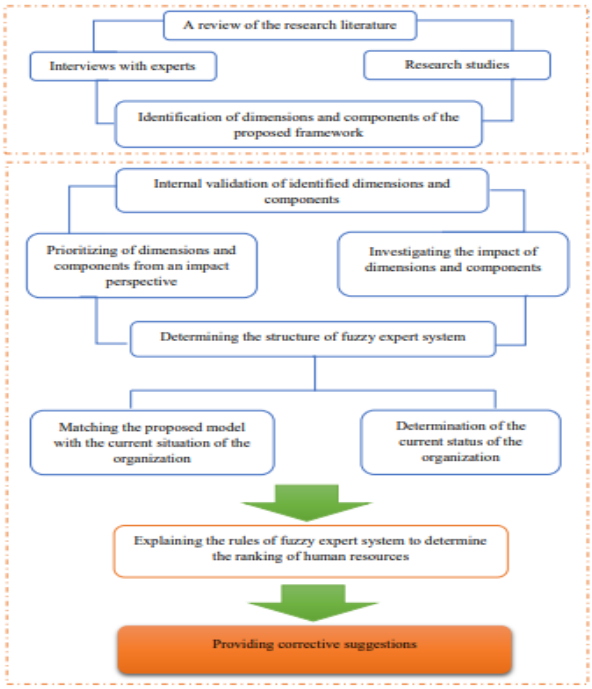

Figure 3. Schematic diagram of the research process

4. Implementation of expert system in accordance with Mamdani fuzzy inference system in a case study

A case study is presented to show how to implement the expert system in accordance with Mamdani fuzzy inference system in previous sections. Evaluation and implementation of the expert system were done in the Imam Khomeini Relief Committee, which is one of the project-based organizations in Iran. The Imam Khomeini Relief Committee has considerable experience in creating a decent organization, better planning, and overseeing affairs. According to the wide field of work and mission in this organization, which is active in the field of housing and employment of the deprived, the nature of each job level in this organization is different, so the proposed fuzzy expert system should be created separately for each job so that the project implementation steps for each team could be done independently in the presence of experts of that unit. To achieve the main goal and implement a meaningful decision model, the following steps were performed:

4.1. Selecting experts

Since the current research scope is the organization of Imam Khomeini Relief Committee, a group of experts in this field were introduced by the organization to play a role as experts through the research and express their opinions in interviews and brainstorming sessions. Therefore, four experts were introduced by the organization.

4.2. Determining the criteria for evaluating human resources and classifying the criteria according to the nature of the jobs

After reviewing articles and studies in the field of human resource productivity and using the opinions of experts, ineffective or repetitive criteria were removed or new criteria were added. In these sessions, a new categorization was considered for the criteria according to strategic, key, and operational jobs (Table 2).

4.3. Weighing the criteria for measuring human resources with Chang fuzzy technique

To determine the importance of each criterion, their weight must be calculated. In this step, experts are asked to determine the importance of each criterion relative to each other based on verbal expressions. To this end, a brainstorming session was held and experts completed a pairwise comparison matrix in consensus. Each value was then converted from verbal expressions to triangular fuzzy numbers using the table to be analyzed (Table 3).

Finally, Chang method was used to obtain the priority and importance of each criterion. Table 4 shows the priority and importance of each criterion, respectively.

The weighting results by the experts' team indicated that managerial, decision-making, psychological, general criteria possess higher priority, manifesting the importance of this issue from their view point.

Table 2. Determining the criteria for evaluating human resources and classifying the criteria according to the nature of jobs

Dimensions	Indices	References	Job classification		
			Strategic	Operational	Support
Managerial	Planning and organizing	Interview with experts	*	*	
	Delegation of authority	Interview with experts	*	*	
	Authority and power of influence	(Bloom and Reenen., 2010)	*		
	Charisma	(Boxall, 1992)	*		
	Systemic and strategic thinking	(Birdi, 2005)	*		
Decision-making	Analysis	Interview with experts	*	*	
	Ability to infer from speech	Interview with experts	*	*	
	Financial analysis ability	(Bloom and Reenen., 2011)		*	
	Creativity	Interview with experts	*	*	
	Risk toleration	Interview with experts	*	*	*
	Flexibility	(Bloom and Reenen, 2011)	*	*	
Communication indices	Listening	(Beardy, 2005)	*	*	*
	Verbal communication	Interview with experts	*	*	
	Content transfer	(Abbasi & Khalil Zadeh, 2021)	*	*	
	Power of presentation	Interview with experts	*	*	*
	Writing ability	Interview with experts	*		
Abilities	Presenting opinion	Interview with experts		*	
	Flexible behavior	Interview with experts	*	*	
	Negotiation	((Bloom and Reenen, 2011)	*	*	
	English proficiency	Interview with experts		*	*
	Familiarity with computer systems and software	Interview with experts		*	*
	Adaptability to conditions	Interview with experts	*		*
Other skills	Attention to details	(Farshad et al., 2020)		*	*
	Ability to learn	(Farshad et al., 2020)		*	*
	Stress toleration	(Farshad et al., 2020)	*	*	*
Business related	Technical	Interview with experts	*	*	*
	Theoretical	Interview with experts	*	*	

Table 3. Linguistic values to determine the priority of criteria over each other

Linguistic values	Fuzzy numbers
Very high	(5/2, 3, 7/2)
High	(3/2, 2, 5/2)
Relatively high	(2/3,1, 3/2)
Equal	(1,1,1)
Relatively low	(2/3, 1, 3/2)
Low	(2/3,1,2/3)
Very low	(2/5, 1/2, 2/3)

Table 4. Prioritization and importance measurement of the criteria by Chang method

Criteria	Scores
Managerial	0/68
Decision making	0/53
Psychological	0/52
General	0/47
Ability	0/41
Communicational	0/20
Business intelligence	0/19

4.4. Determining the structure of fuzzy expert system and determining the value of criteria

In this step, by holding in-depth interviews and brainstorming sessions for all selected qualitative criteria, the relevant verbal variables are determined, and for quantitative criteria, specific ranges are considered that are used in fuzzification of inputs. Then, the fuzzy ranges of all the criteria are specified, and finally their membership functions are defined. Another important component of the fuzzy expert system is the knowledge base of the system, which is formed at this stage. Knowledge engineering should be done, and the knowledge and experience of experts should be extracted by holding in-depth interviews and numerous brainstorming sessions, and their mental model should be structured and the rules of the expert system should be created. Also, a group of experts was selected by the senior management of the organization, which may be different from the previous group due to the breadth of the organization's field of activity, to value the criteria approved in the previous step by fully evaluating the criteria. After the criteria are quantified by experts, the verbal values are converted into fuzzy numbers and the decision matrix is formed, and then the average of their comments is calculated, and a unit value is determined for each criterion, and in fact fuzzification ends. Accordingly, to achieve the specific goals presented in the first step, the structure of the expert system based on Mamdani fuzzy inference system, four main criteria, and sub-criteria of each are determined as Figure 4.

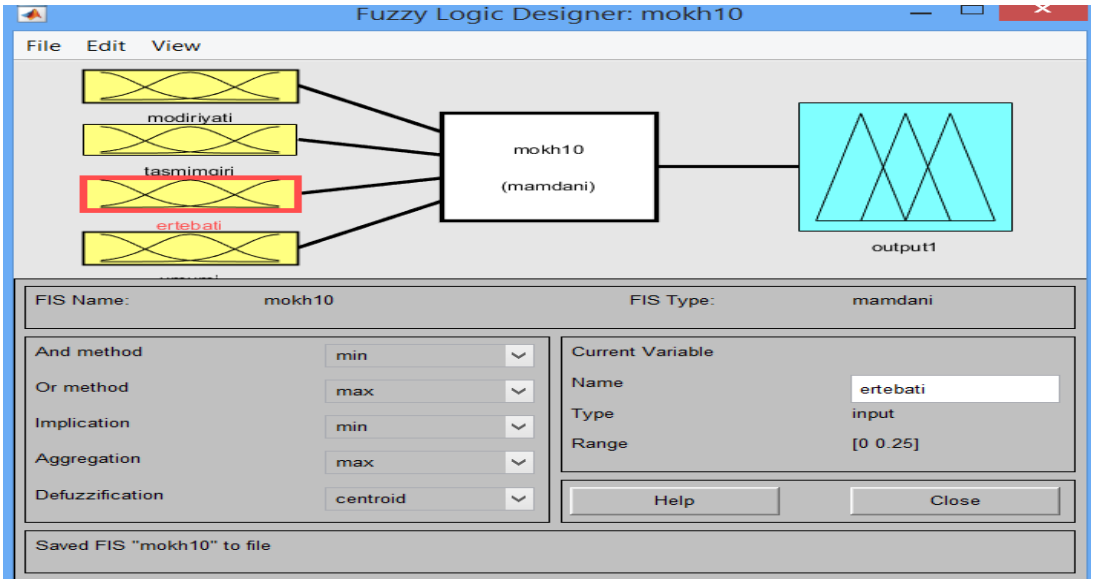

Figure 4. Definition of four main criteria

In the second step, the sub-criteria are defined based on the number and fuzzy triangle functions shown in Figure 5.

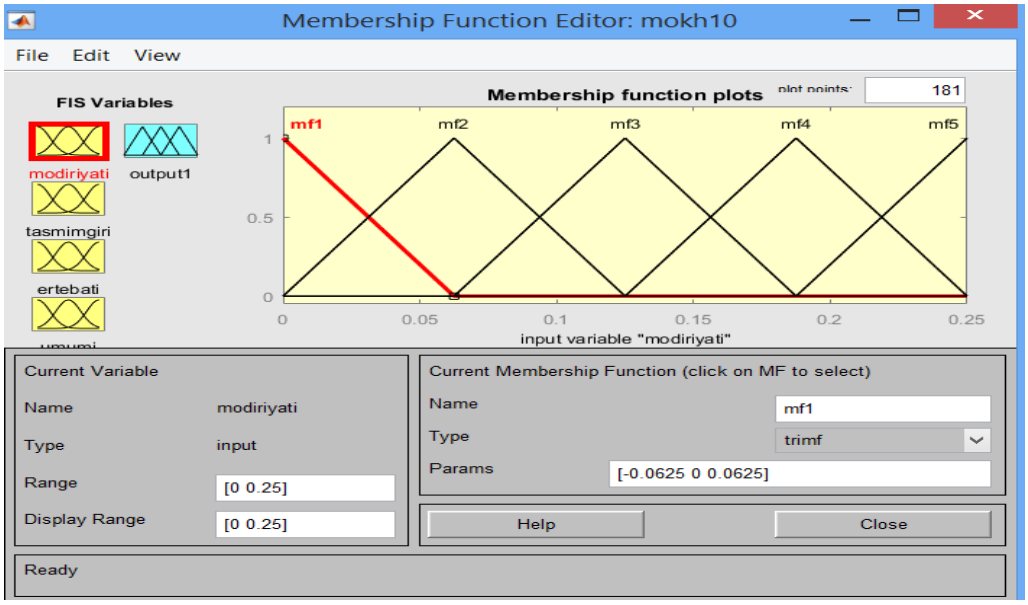

Figure 5. Definition of sub-criteria based on the number and fuzzy triangle functions

In the third step, the range of three strategic, key, and operational outputs is defined (Figure 6). The range of outputs is defined for values less than 0.4 for strategic dimension 0.4 to 0.8, for key dimension and greater than 0.8 for operational dimension.

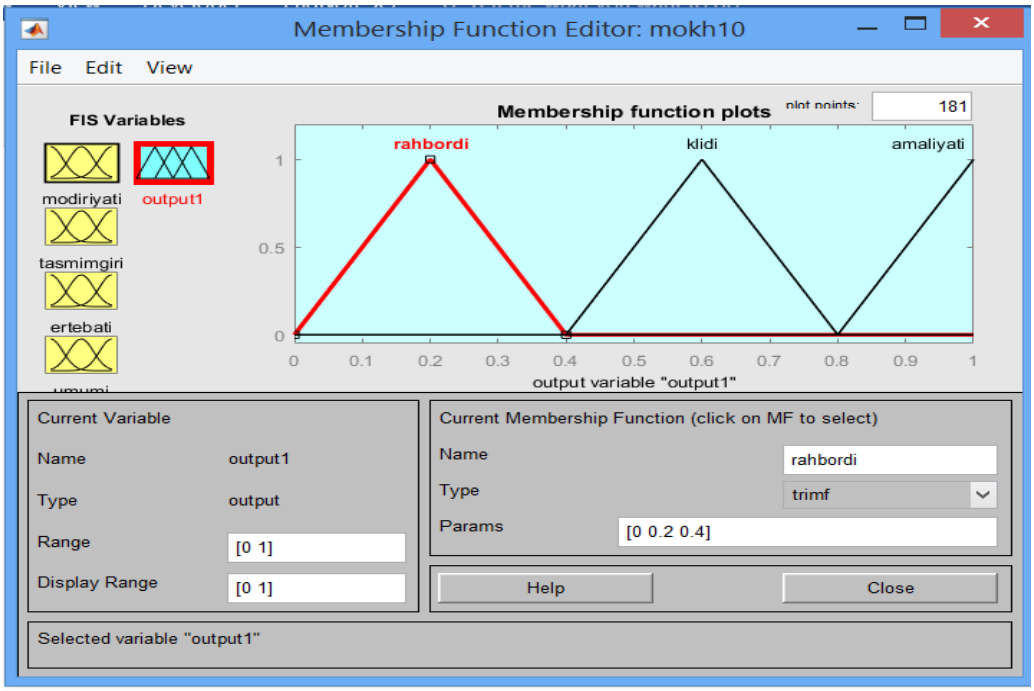

Figure 6. Definition of three strategic, key, and operational outputs

In the fourth step, 39 rules are defined according to Figure 7. For example, for the first rule, if the first sub-criterion had a defined value in the inputs, then it would display the strategic and key output as a result.

Finally, in the fifth step, the limits of fuzzy rules can be seen (Figure 8).

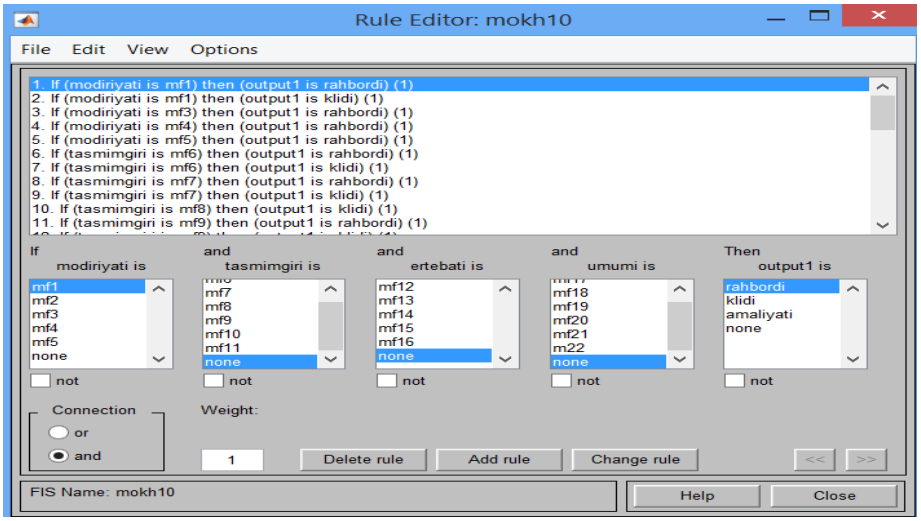

Figure 7. Definition of fuzzy inference rules

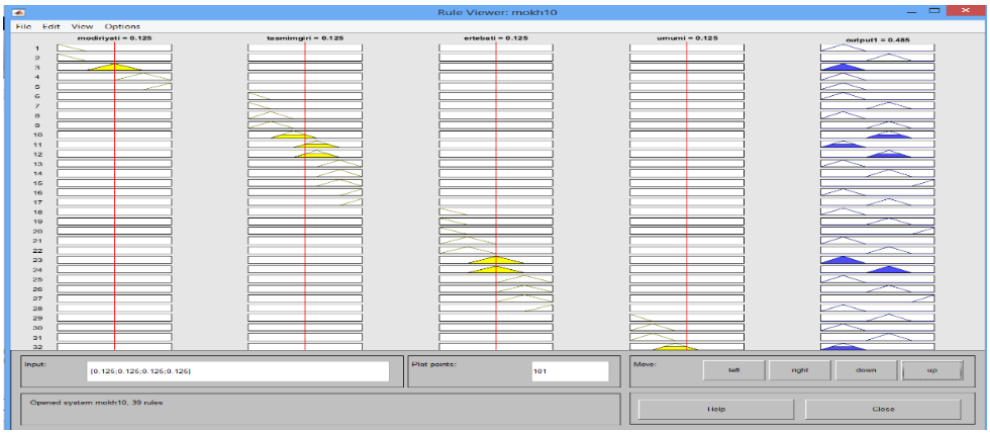

Figure 8. Limits of fuzzy rules

In the sixth and final step, four weights can enter as input, and the output result can be observed. In the last line, considering the inputs [0.3, 0.2, 0.1, and 0.4], managerial, decision-making, communication indices and general abilities and psychology can be seen.

4.5. Assessing human resources through fuzzy expert system in accordance with Mamdani fuzzy inference

According to the values determined for each criterion in the previous step and the formation of the knowledge base of the fuzzy expert system, using the Mamdani method, the fuzzy inference operation is performed, and the desired output is obtained. After defuzzification, the rank of each human resource is determined. Accordingly, human resources are assessed step by step based on the three-dimensional view.

In the first case, the impact of management and decision-making dimensions on three important outputs are discussed, including strategic, operational, and support jobs. Figure 9 shows a three-dimensional view of human resource measurement, in which the length and width are two dimensions of decision-making and management, and the height is the measurement of human resources. The results present changes in the management range of 0 to 0.2 in the range of 0 to 0.15 decision-making of outputs less than 0.49 related to the key criterion, but in the range of 0 to 0.2 management and in the range of 0.15 to 0.25 decision-making increase, and its value reaches 0.51.

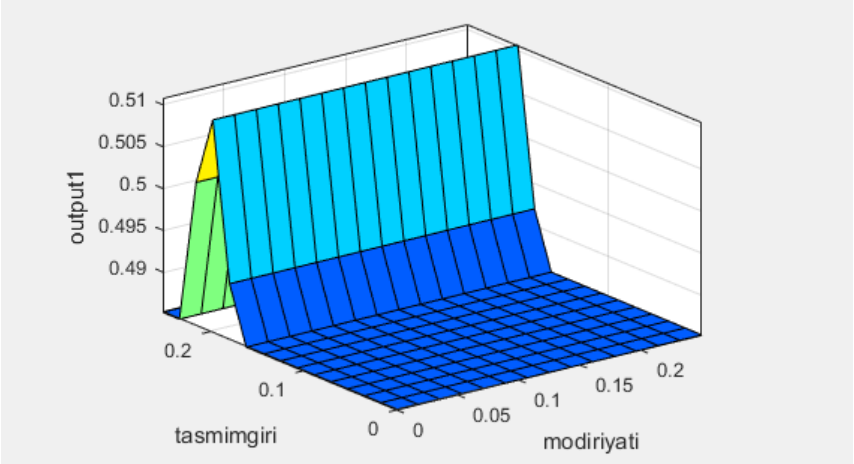

Figure 9. The defined level for the two criteria of management and decision making

Similarly, Figure 10 shows the defined fuzzy level for both management and communication criteria. Based on the results, changes in the management range of 0 to 0.25 in the range of 0 to 0.25 show the relation of different outputs, and the outputs are in the range of key criteria. The analysis of the results shows that if two managerial and communication criteria are considered for the selection of manpower, the desired manpower will be suitable for key jobs in the organization after the necessary evaluations and can be employed in the positions of workshop manager, designing and engineering manager, equipment supply manager, planning manager, procurement and organization of human resources, marketing manager, finance manager, and insurance manager, thus increasing productivity in the organization.

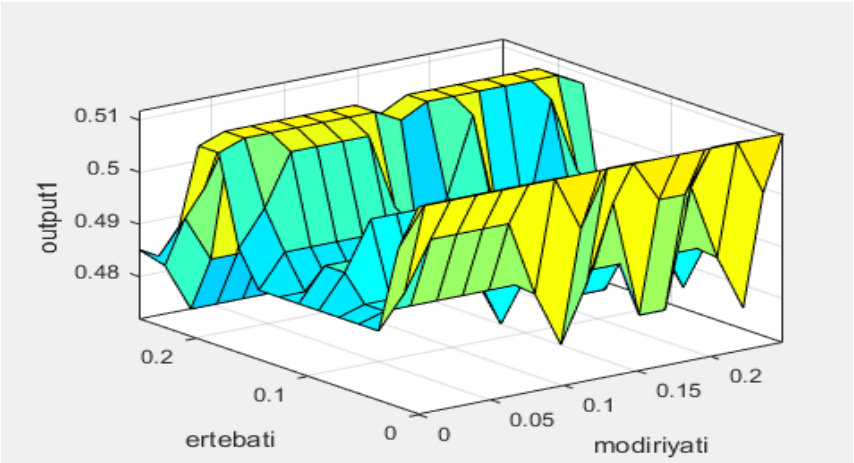

Figure 10. The defined level for both management and communication criteria

Figure 11 shows the fuzzy defined level for both managerial and general criteria. Based on the results, changes in the management range of 0 to 0.25 in the general range of 0 to 0.1 provide 0.4 outputs, which is related to the strategic criterion, and in other values, outputs are in the key range. The analysis shows that the selected workforce, considering both management and general criteria, can be employed, considering the importance of the organization, to increase the productivity of human resources in the jobs of the deputy chief executive officer, specialized deputies, and managers of subsidiaries, and increase the efficiency of the organization and prevent the failure of important projects in the organization. The analysis of the three-dimensional view shows that the desired workforce can be employed in some positions related to key jobs due to his eligibility in addition to strategic jobs.

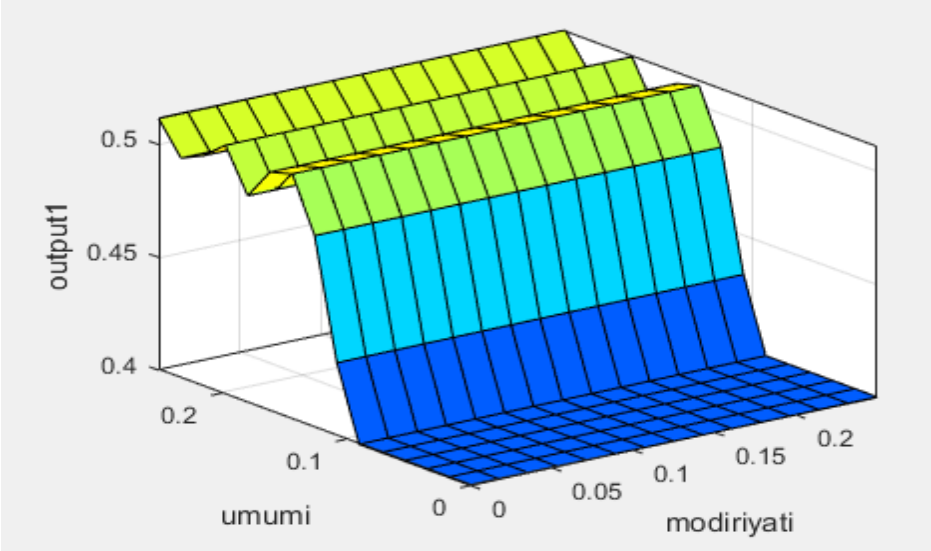

Figure 11. The defined level for both managerial and general criteria

Figure 12 shows the fuzzy defined level for both decision-making and communication criteria. Based on the results, changes in the decision-making range of 0 to 0.25 in the 0 to 0.25 range provide the relation of different outputs, the outputs of which are within the key criteria range.

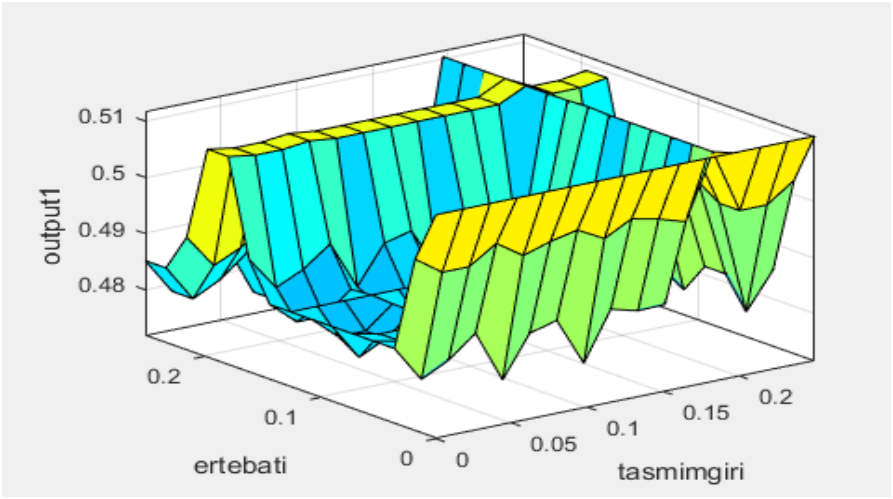

Figure 12. The defined level for both decision-making and communication criteria

Figure 13 shows the fuzzy defined level for both decision-making and general criteria. Based on the results, changes in the decision-making range of 0 to 0.25 in the general range of 0 to 0.25 offer different outputs, which are in the range of strategic and key criteria. The analysis of Figure 13 is the same as the previous cases, i.e., if the person in question has two dimensions related to decision-making and general dimensions, he can be the deputy chief executive officer, in charge of specialized deputies, and manager of subsidiaries in strategic jobs. In key group jobs, he can be a workshop manager, designing and engineering manager, equipment supply manager, planning manager, resource management and human resource organization, marketing manager, finance manager, and insurance manager and take an effective step to increase the productivity of human resources in the project-based organization.

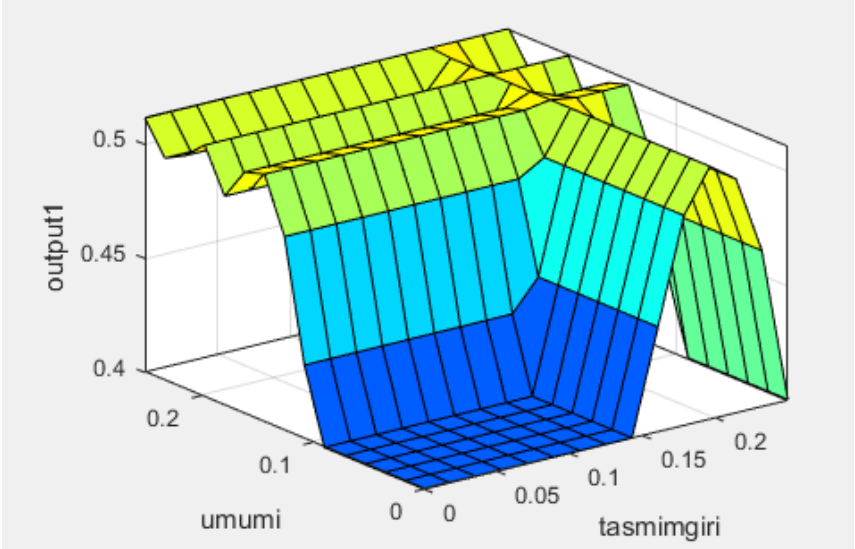

Figure 13. The defined level for both decision-making and general criteria

Figure 14 shows the fuzzy defined level for both communication and general criteria. Based on the results, changes in the communication range of 0 to 0.25 in the general range of 0 to 0.25 show different outputs that are within the strategic and key criteria.

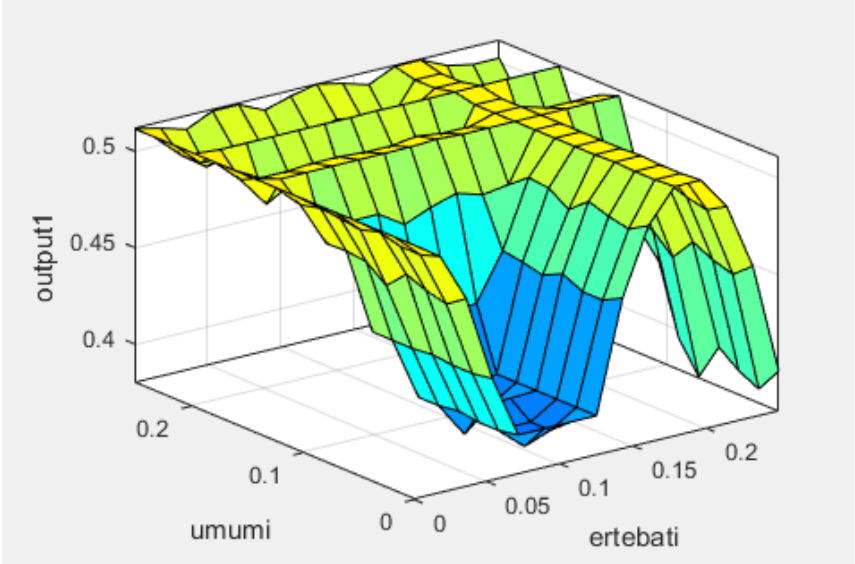

Figure 14. The defined level for both communication and general criteria

5. Discussion

The progress of a country depends on the correct and effective use of human resources and how it is managed. Skilled and experienced human resources is the main axis of sustainable development and with its proper use, the future of organizations can be guaranteed. In this regard, by implementing the philosophy of purposeful planning for human resource management, and acceptable compatibility between the demands of employers and employees can be achieved. To improve human resource management, the first step is to pay attention to the important issue of manpower training in the organization. A review of research in recent years shows that various studies have been conducted in recent years. One of them is the research of Farshad et al. (2020) assessed the factors affecting the improvement of human resources. They revealed that the professional behavior of citizens (individual characteristics,

social responsibility, and behavior in society), job performance (professional performance, organizational performance, and research performance), and innovation (individual, organizational, and social) are the important effective factors affecting the improvement of human resource measurement, which are the basis for the production and provision of services in organizations and one of the basic strategies in increasing efficiency and productivity. Outman et al. (2018) provided a framework for examining effective human resource management in the construction industry. The results of the research led to the identification of 11 indicators in the field of improving human resource management. These indicators, after survey and weighting, include designing and decision-making, benefiting from a ready and fresh workforce, law enforcement, employee behavior, inter-employee communications, effective employee management, employee training, having specialized knowledge, staff empowerment, and development of instructions, respectively. Mila and Soodi (2021) presented a model to evaluate human resource improvement programs in the organization. They identified factors affecting the measurement of human resources in the organization.

Although various models and frameworks for measuring human resources in project-oriented organizations have been presented, the important issue in measuring human resources is to provide an expert system that can provide results with high reliability and accuracy and in the organization. Implemented large project-oriented projects. To this end, the fuzzy inference system is felt to be a response to this need. Because of the use of fuzzy expert systems in the meantime, the elimination of bureaucracy and inappropriate administrative procedures to achieve the potential abilities and talents of individuals seems necessary. For this purpose, according to the study gap identified by researchers, to measure human resources in the construction industry, an expert system based on a fuzzy inference system has been proposed. In comparison with the researches of Farshad et al. (2020), Outman et al. (2018), and Mila and Soodi (2021) which only dealt with the effective factors on measuring human resources in organizations and the productivity criteria in each job, with paying attention to the organization's human resource management strategies, utilizing the experiences of experts in determining the effectiveness of each job criterion in selecting employees, maintaining the information of each job applicant for future planning of the organization (career development path planning, promotion, determining the effectiveness of training courses, determining the replacement table of positions), preventing tasteful choices in selecting employees, documenting the job applicant's privilege and using it when necessary, having an evaluation software, selecting and the appointment of human resources in the organization and finally the selection of qualified people to improve the status of the organization in the business environment, have not paid attention can be useful and constructive. In this article, we tried to present a real application of the expert system based on Mamdani fuzzy inference system to measure the criteria affecting productivity in hiring employees in three levels of strategic, key, and operational jobs. According to the findings on the status of managerial, decision-making, communication, and general dimensions and the final output of the system (measuring human resources to replace employees in one of the strategic, operational, and support jobs), the capacity of human resources should be strengthened and planned to increase their efficiency in the organization, taking into account the current capabilities and criteria of the general administration office and the gap between the current situation and the desired situation. Also, according to the human resource management strategies of the organization, utilizing the experiences of experts in determining the effectiveness of each of the job criteria in selecting employees, maintaining the information of each job applicant for future planning of the organization (career development path planning, promotion, determining the effectiveness of training courses, determining the replacement table of positions), preventing tasteful choices in selecting employees,

documenting the job applicant's privilege and using it when necessary, having a software evaluation, selection and appointment of human resources in the organization and finally the selection of qualified people to improve the status of the organization in the business environment.

6. Conclusion

In today's advanced and social world, organizations are social systems in which human resources are the most important factor in their effectiveness and efficiency. To achieve their goals, they need effective employees with optimal performance and without the effort and commitment of their employees, they will not achieve success. Organizations need continuous performance improvement to maintain their survival and progress, and human resources are considered the core assets of organizations and the source of any change and innovation. In this regard, human resource assessment is an essential task in achieving organizational goals and missions. Human resource assessment is one of the most complex and important processes in project-based organizations. Very important because the productivity of the organization depends on the productivity of its human resources and is complex because it requires consideration of more than one criterion and therefore the judgment and intuition of decision-makers when measuring human resources. Decision makers' judgments are based on their vague and unknown knowledge, expressed through linguistic words. In human judgment, there are ambiguous preferences, and in most situations, human beings do not have accurate knowledge of phenomena and cannot express their ideas and judgments with a numerical value. A realistic approach in such situations is the fuzzy approach in which decision-makers can use linguistic words and qualitative terms to express their judgments and preferences. The fuzzy approach overshadows most of the processes of human thought and perception of phenomena. Fuzzy set theory shows the mentality of human behavior. This theory provides a modeling tool for the uncertainty that emerges from the human mind, which is not random and static; this theory has been introduced to manage inaccurate information in real-world decision-making issues. Thus, fuzzy set theory can be very suitable for optimally performing the tasks of workforce assessment and deciding whether to accept or reject a job candidate. But the important issue, in addition to considering fuzzy theory, is to design an expert system that can provide results with high reliability and accuracy and implement them in large project-based organizations. To this end, the fuzzy inference system based on the Mamdani system is a response to this need. In this article, we tried to present a real application of the expert system based on the Mamdani fuzzy inference system to measure the criteria affecting productivity in hiring employees in three levels of strategic, key, and operational jobs. According to the findings on the status of managerial, decision-making, communication, and general dimensions and the final output of the system (measuring human resources to replace employees in one of the strategic, operational, and support jobs), the capacity of human resources should be strengthened and planned to increase their efficiency in the organization, taking into account the current capabilities and criteria of the general administration office and the gap between the current situation and the desired situation. Obviously, to implement this model in other organizations, the values of the designed fuzzy inference system must be defined specifically for the organization, and the models should be simulated by examining their components and relationships, and through them, human resources should be assessed in project-based organizations. The present study faces limitations including:

1) In the present study, the evaluation of human resources was performed based on the productivity and key criteria of the organization and was not studied and analyzed in detail in

terms of how to improve the approach, commitment, style, and demands of managers. Accordingly, it is suggested that human capital productivity be done from the perspective of mechanisms needed to intersect productivity processes and key processes of the organization and analyzed in detail from the perspective of how to improve the approach, commitment, style, and demands of managers.

2) In the present study, in order to identify and weigh the decision criteria, brainstorming sessions and Chang Fuzzy decision technique were used and the relationship between the decision criteria was not considered. In this regard, in order to complete and develop the conceptual model, it is suggested to use other qualitative research methods such as Confirmatory Factor Analysis (CFA), Structural Equation Model (SEM), etc.

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