International Journal of Industrial Engineering & Production Research (2016)

September 2016, Volume 27, Number 3
pp. 243 -264

http://IJIEPR.iust.ac.ir/

Developing a Fuzzy Group Decision-Making Approach for Project Manager Selection Considering the Static Complexity of Construction Projects

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KEYWORDS

Construction industry,
Project manager,
Competency,
Static complexity,
Fuzzy set theory,
Group decision-making

ABSTRACT

Due to the particular importance of projects in human life and in organizations, proper project management has been always regarded highly by researchers and practitioners. Recent advances in technology and fundamental changes in most scientific areas have affected projects and made their nature and environmental circumstances much more complex compared to the circumstances in the past. Fortunately, in recent years, many scholars have recognized the importance of complexity in modern project management and tried to identify its various aspects. Furthermore, one of the main factors for a project's success is the assignment of an appropriate project manager. Many studies have been done about project managers' competencies and the selection methods of a suitable project manager. In most of these studies, the amount and type of project complexity have been explained as influential factors for determining the competent project manager. However, a specific approach for project manager selection considering the project complexity is not provided yet. Hence, in this paper, we try to design and implement a fuzzy group decision-making approach to select the best project manager taking into account the project complexity. Also, owing to the importance of construction projects in the development of countries' basic infrastructures, we exclusively studied this kind of projects. Finally, it should be noted that from the viewpoint of complexity theory, system complexity can exist in two forms: static and dynamic. Therefore, considering the breadth of issues related to each of these two complexity areas, just the static complexity of construction projects has been studied here.

1. Introduction

Projects are very pervasive in today's world, such that people and organizations are always involved in a variety of them. Almost all projects are distinct from each other, and they can be considered by two main aspects: inherent features and environmental conditions. Some inherent features are project type, scope, duration, budget, and product. Environmental conditions are project location, stakeholders, risks, laws, and policies. You can rarely find two projects that are absolutely identical. Meanwhile, due to the particular importance of projects in human life and in organizations' business, proper project management has been always regarded highly by researchers and practitioners. Activists in this area are consistently looking for appropriate techniques and methods for the management of various projects, and success in achieving their predetermined objectives *(Ebrahimnejad et al., 2014)*. These efforts have led to the formulation of different project management standards and methods for evaluating and analyzing projects' diverse characteristics.

On the other hand, recent advances in technology and fundamental changes in most scientific areas have affected projects and made their nature and environmental circumstances much more complex than the circumstances in the past. Today, more advanced technologies are often used in projects execution, their scope and scale are expanded, extended supply chains are possessed, the number of project stakeholders is increased, etc. These complexities have led organizations mostly to fail to finish a project within the prescribed duration by the approved budget and according to the desired quality. In other words, projects have frequently failed to achieve their goals or have been underperforming recently *(Sun et al., 2015)*.

In such conditions, the customary principles and practices of project management that ever used are not anymore able to handle the emerging complexities of projects. In the traditional project management frameworks, only the common dimensions of a project, such as time, cost, and quality, were considered. Newer project management models also consider many other aspects, such as project risks and changes *(Xu and Lin, 2015)*. However, with the increasing complexity in projects, these dimensions cannot completely describe a project's behavior any longer. Indeed, one of the key features of projects is the project complexity, which has an essential role in the project's success and failure and can be a source of new risks.

Fortunately, in recent years, many scholars have recognized the importance of complexity in modern project management and tried to identify the various aspects of project complexity and provide appropriate solutions to deal with them. However, the maturity of project management science in the complexity field is still very low and has not much progressed compared to the other areas of project management knowledge. Most of the studies in this regard only provide some basic conceptual models and just identified a number of project complexity factors. Hence, further efforts and studies are necessary to provide a comprehensive framework for the integrated management and control of project complexity *(Vidal et al., 2013)*.

Furthermore, one of the main factors of a project's success is the assignment of an appropriate project manager, but allocating the most qualified project manager can be a big challenge due to the multiple dimensions that should be considered *(Fisher, 2011)*. Employing an inadequately prepared project manager, without the required knowledge and experience, is something that could threaten the success of a project; in this way, he would probably not be able to decently manage the project in all its aspects *(Müller and Turner, 2010)*. Many studies have been done on project managers' competencies and the selection methods of a suitable project manager. In most of these studies, the amount and type of project complexity have been explained as influential factors for determining the competent project manager. However, a specific approach for project manager selection considering the project complexity is not provided yet.

Due to the ambiguity and uncertainty of complexity context, the subjective nature of competency evaluation and the difficulty of the exact quantification of complexity and competency values based on available information, the application of fuzziness could be very appropriate. In the real world, humans understand and use many concepts in the form of fuzzy, i.e., imprecise, unclear, and vague. As numerical variables are used in the mathematical calculations, linguistic variables are used in the fuzzy logic *(Sadi-Nezhad et al., 2013)*. Linguistic variables are expressed based on their linguistic values. Hence, in this paper, we have tried to design and implement a group decision-making

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Received 31 october 2016; revised 12 December 2016; accepted 16 January 2017

approach in the fuzzy environment to evaluate the project complexity and allocate the best project manager.

Construction industry encompasses a variety of projects, such as roads, dams, power plants, factories and airports. Many construction projects have not yet secured good project goal achievement. Such a failure could be realized in terms of severe project delay, cost overrun, and poor quality *(Nasirzadeh et al., 2013)*. Thus, long-run time, high costs, multiple stakeholders, and various risks are some characteristics of most construction projects, which led these projects to become very complex *(Afshari, 2015)*. Their complexity has led executive organizations to often fail to achieve the objectives of construction projects. Moreover, owing to the importance of construction projects in the development of countries' basic infrastructures, we have exclusively studied these kinds of projects. Finally, it should be noted that from the viewpoint of complexity theory, system complexity can exist in two forms: static and dynamic. Static complexity reflects the structural complexity of a project. This type of complexity shows the inherent features or environmental conditions of projects. In contrast, dynamic complexity is associated with the diversity and changes of a project's operational behavior over time. Actually, dynamic complexity is derived from the direct observation of projects' behavior. Therefore, considering the breadth of issues related to each of these two complexity areas, just the static complexity of construction projects has been studied here.

The content of this study is presented in the following seven main sections. The next section reviews the literature on project manager selection and project complexity evaluation. Section 3 describes the proposed classification structure of project manager competencies, project complexities, and the relationships between competency criteria and complexity factors. The overview of fuzzy set theory is given in section 4. Then, the proposed approach, i.e., a fuzzy group decision making approach for project manager selection considering the project complexity, is presented. Section 6 shows how to implement this system through a case study on a number of power plant projects. At the end of the article, the results and findings of this research and also the proposed future studies are summarized.

2. Literature Review

2-1. Project manager selection

Mohd Derus and Abdul-Aziz (2016) conducted a research to examine the technical competencies of project managers required by Malaysia's Public Works Department. Using the Delphi Technique to collect data from senior staff, Hanna et al. (2016) provided the construction industry with a generic mathematical formulation to reliably weigh different project manager competencies. The developed data-driven mathematical model reflects the relative importance that industry practitioners place on different project manager competencies while distinguishing exceptional project managers from average ones. Jaafar et al. (2016) sought to put forward a model assessing the female project managers' competency level within the context of the Malaysian construction industry. This study qualitatively tests the proposed framework, which is quantitatively constructed based on several competency models introduced in previous literature.

Chaghooshi et al. (2016) proposed the joint use of the fuzzy DEMATEL and fuzzy VIKOR methods for the decision-making process of selecting the most suitable managers for projects. With the opinions of the senior managers based on project management competency model (ICB-IPMA), all the criteria required for the selection were gathered. Erasmus et al. (2016) determined factors in personal and performance competencies. This quantitative study utilized a survey that was distributed among project managers in South Africa. The responses were analyzed by way of factor analysis to determine whether sub-competencies can be grouped into related topics. Cassar and Martin (2016) recognized that interpersonal uncertainties are often neglected in project manager selection, and this may produce less accurate decisions. Cloud theory was shown to be accurate in the representation of a person's judgement with reality. So, they developed a computerized model which incorporates both random and fuzzy uncertainties of decision-making in the construction industry.

Afshari (2015) provided a systematic technique for project manager selection problem of construction projects by using a modified Delphi method for criteria selection and group fuzzy linguistic evaluation to rank candidate project managers. Dodangeh et al. (2014) also developed a new linguistic reasoning for fuzzy group decision making to aggregate the subjective evaluations of decision-makers and select the best

project manager for a construction project. Sadeghi et al. (2014) presented a construction project manager competency model and an evaluation method, which utilize a goal programming technique to calculate the interval weights of criteria and use TOPSIS technique with interval weights and judgment data to select the competent project manager.
Ahadzie et al. (2014) designed a structured questionnaire and identified the core competencies that project managers must possess at the design phase of the lifecycle of construction projects. The data were then subjected to multiple regression analyses towards isolating the relevant competencies. Varajão and Cruz-Cunha (2013) proposed the joint use of AHP and IPMA competence baseline as a tool for the decision making process of selecting the most suitable manager for construction projects. They constructed a hierarchical structure, comprising the IPMA competence elements. Zhang et al. (2013) attempted to identify and evaluate the key social competencies of project managers in the construction context. This led to the development of a model via the use of a structural equation modelling approach.
Othman and Jaafar (2013) used a questionnaire survey approach and stratified random sampling design to assess the personal competency level of women project managers in the Malaysian construction industry. Ahsan et al. (2013) addressed the competencies organizations use through project manager job advertisements and conducted a comparative analysis of the use of these competencies. Afshari et al. (2013) suggested a new model for personnel selection in the construction projects using fuzzy linguistic variables with multi-criteria decision making and proposed a new linguistic extension of fuzzy measure and fuzzy integral in order to control the dependency which may exist among criteria.
Safarzadegan Gilan et al. (2012) established a hierarchical competency criteria structure and presented a computing with words approach, based on the specific architecture of perceptual computer and the linguistic weighted average, for the competency based evaluation and selection of human resources in the construction firms, where all linguistic terms were characterized by the interval type-2 fuzzy sets. Shahhosseini and Sebt (2011) presented a fuzzy adaptive decision making model to evaluate and rank the different types of competent construction personnel. Decision making was performed in two stages: a fuzzy AHP for evaluating the competency criteria and an adaptive neuro fuzzy inference system for establishing the competency If-Then rules of the fuzzy inference system.
Lin (2011) proposed a decision making model for human resource allocation in remote construction projects by estimating total project cost as the project level risks. He used Delphi and fuzzy AHP process to practically evaluate the proficiency between in-house and local employees, helping decision-makers to estimate their potential project losses. Ahadzie et al. (2008) provided a potentially useful contextual-task framework that can further an in-depth understanding of the competency profiles of project managers. This framework distinguishes contextual performance behaviors from task performance behaviors and is used to predict the performance of project managers in the construction industry.

2-2. Project complexity evaluation

Zhu and Mostafavi (2017) proposed an integrated performance assessment framework based on consideration of complexity and emergent properties in project systems. It has been shown that a greater level of congruence between project emergent properties and complexity can potentially increase the possibility of achieving performance goals in construction projects. Schuh et al. (2016) presented an approach for complexity evaluation of projects during project preparation. The approach is based on complexity drivers. Interdependencies between the complexity drivers were analyzed using the influence matrix and they were segmented in an influence portfolio. Qazi et al. (2016) explored a new process that aids capturing interdependency between project complexity, complexity induced risks, and project objectives. The proposed modelling approach was grounded in the theoretical framework of expected utility theory and Bayesian belief networks.
Padalkar and Gopinath (2016) developed the taxonomy of constituent terms of complexity and uncertainty in project management, based on semantic analysis of selected literature, and showed that the two constructs are broadly confounded in their constituent terms. Floricel et al. (2016) investigated how complexity influences projects and their performance. They identified specific strategies for organizing and knowledge production that project planners use to address complexity-related uncertainties. They also theorized about the way these strategies interact with various types of complexity to increase project performance. Ellinas et al. (2016) used empirical activity networks to account for

the technological aspect of five projects. So, a procedure for the quantitative assessment of structural complexity of project was presented and results of the analysis were used to highlight qualitatively similar behavior with a well-known complex system, the Internet.

Qureshi and Kang (2015) identified and modeled organizational factors to assist project managers in handling these factors of project complexity in a more regulated fashion. The model was developed using structural equation modelling technique. Nguyen et al. (2015) distinguished project complexity factors, specifically for transportation construction and deduced a hierarchical structure of the main components of project complexity using factor analysis. They also employed the fuzzy AHP method to determine the weights of the components and parameters of project complexity, and finally a complexity level was proposed to measure the overall project complexity. Lu et al. (2015) used the task and organization perspective to propose a measurement model of the large-scale projects complexity through hidden workload that reflects the dynamic and emerging effect of influencing factors on project complexity. Task and organization measures were identified and mapped with the attribute settings of ProjectSim simulation software.

Li et al. (2015) developed an urban infrastructure multi-project management information system to decompose the information processing complexity in the context of a special project management mode. The complex adaptive system, two specific development techniques, adaptive project framework, and modularized functional design method were introduced for the system development. He et al. (2015) formulated a systematic complexity measurement model based on a mega construction project in China using the fuzzy ANP approach. Giezen et al. (2015) explored the mechanisms that enhance or limit the adaptive capacity used to reduce the complexity of decision making and planning process. They developed the concept of adaptive capacity using organizational learning theory and used empirical data from a mega infrastructure project to identify the moments of adaptation and to discern these mechanisms. Sanati and Noori (2015) attempted to describe the complexity of project using three approaches; research literature, interviews, and questionnaire. To this end, the project complexity factors and parameters were identified. In addition, using WH questions technique, which analyzes the project complexity from all aspects, a 5P model (Purpose, Product, Process, People, and Peripheral) was introduced.

Bosch-Rekveldt et al. (2015) investigated the drivers of complexity in engineering projects according to literature and empirical data. The empirical data were gathered by means of case studies in which interviews were held with the persons of different projects. Ramasesh and Browning (2014) presented a conceptual framework to recognize and reduce knowable unknown unknowns in project management. In this framework, they presented a model of the key factors, such as complexity, which increases the likelihood of unknown unknowns and a set of propositions linking these factors to unknown unknowns. Lessard et al. (2014) focused on the relationship between various project features and properties associated with complexity and proposed a combined structural and process-based theoretical framework for understanding and interpreting the contributors to complexity in large infrastructure projects.

Vidal et al. (2013) reviewed the literature in order to build a standardized project complexity framework. Then, they described how a Delphi study was conducted over a panel of academic and industrial experts to refine it and use the AHP method to assess project complexity on different project alternatives, given their project complexity framework. Senescu et al. (2013) applied complexity and virtual design and construction research to contribute a method for assessing product, organization, and process complexity. Through project team interviews, they also contributed a communication assessment method and proposed a trend between increased project complexity and increased communication challenges.

Gransberg et al. (2013) designed a framework upon which a complex transportation project's scope of work can be better conceptualized and also proposed a methodology to graphically display a project's complexity in order to better understand and prioritize the available resources. Jenab et al. (2012) presented a fuzzy graph-based model to measure the relative complexity of projects that uses an aggregation operator to resolve conflict among experts with respect to a complexity relation. The model maps the fuzzy graph into a scaled Cartesian diagram that depicts the relative degree of complexity among projects. Xia and Chan (2012) conducted a three-round of Delphi questionnaire survey to identify the key parameters that measure the degree of complexity for building projects, and a complexity index was developed based on the identified measures and their relative importance.

3. The Proposed Classification

In the primary parts of this study, we have tried to make clear the importance of complexity in project management. In summary, we concluded that complexity is undoubtedly one of the main obstacles in achieving the preset objectives of a project. Then, it was pointed out that in order to control and mitigate the negative effects of project complexity, it should be evaluated first. In this regard, the initial step is to identify the key factors that create project complexity. Therefore, a comprehensive literature review was done in the previous section, and the main project complexity factors provided in recent years by other researchers have been introduced. Now, in this section, we will describe our proposed classification structure of project complexity factors. Surely, project complexity factors are very extensive and we can classify them from different aspects. According to some other studies, it is concluded that project complexity originates from four main sources, comprising *organization*, *features*, *resources,* and *environment*. Also, complexity factors can be categorized based on internal or external as well as controllable or uncontrollable aspects.

The first group of project complexity factors originates from organization. To be more precise, they are about how to plan, conform and negotiate in a project. It's clear that organizational factors are internal and controllable. This means that we could improve their conditions, some of these factors include project *schedules*, *contracts* and *requirements*. The other internal source of project complexity is the inherent features of a project, such as project *scope*, *objectives,* and *technologies*. Unlike the first group, this type of complexity factors is uncontrollable and we are not able to change or remove them. The third category of project complexity factors is related to resources. We consider them as an external source of complexity. Just like organization, they are also controllable. For instance, we can mention *contractors and suppliers*, *team* and *information systems*. The last source of complexity factors is project environment. Anything capable of affecting the project is called the project environment. It is obvious that environmental factors are external and uncontrollable, such as *stakeholders*, *laws and regulations,* and *geography and climate*.

On the other hand, organizations are always looking for competent project managers to direct their projects activities. The notion of competency originates from the Latin word *Competentia* which means "be authorized to judge" or "having the right to speak". Nowadays, there are many different definitions about the competency concept. For instance, IPMA Competence Baseline (ICB) describes competency as a collection of knowledge, personal attitudes, skills, and relevant experience needed to be successful in a certain function *(International Project Management Association, 2006)*. Also, Project Manager Competency Development (PMCD) Framework describes competency as the demonstrated ability to perform activities within a project environment leading to expected outcomes based on the defined and accepted standards *(Project Management Institute, 2007)*.

A project manager must have a set of required competency criteria for a specific project to conduct it successfully. Required competencies for a project manager should be changed according to factors, such as type and characteristics of the project. In fact, potential differences in the importance of particular competencies, given certain project type or characteristics, still need to be considered during the application of a project manager competency model *(Project Management Institute, 2007)*. As noted, one of the most important of these characteristics is the project complexity. In this section, we will try to define the key aspects of competency, identify those competencies that are most likely to impact project manager performance, and determine the relationships between project manager competency criteria and project complexity factors. As mentioned in the previous section, there are various models for the classification of project managers' competencies. Based on a comprehensive review of these models, the identified competency criteria of our proposed approach are classified in four aspects of *management*, *knowledge*, *performance*, and *behavior*.

The first category of project manager competency criteria includes management competencies; some of these criteria comprise the project manager's abilities of *planning*, *negotiation*, and *conformity*. Management competency criteria are related to the organizational complexity factors. In fact, by enhancing the management competencies of a project manager, we can control and mitigate the negative effects of project complexities which originate from the organization. Therefore, if the organizational complexity of a project is very high, we should select a project manager with very good management aspect and skill. The other element of competency for project managers is called knowledge, such as project manager's *education and experience*, *cognition and control* and *trade-off* skills. Knowledge competency criteria are related to the complexity factors that originate from the inherent features of project. The third group of project manager competency criteria is associated with performance competencies. For instance, we can mention *leadership and development*, *coordination* and *organizing* abilities. Performance competency criteria are related to the other source of complexity in projects, which is resources. The last dimension of competency for project managers is named behavior, such as *communication*, *compliance*, and *adaptation*. Behavioral competency criteria are related to the project's environmental complexity factors.

Finally, after an investigation and comprehensive analysis of the competency criteria and the complexity factors, twelve project manager competency criteria and twelve project complexity factors were identified and shown in Tables 1 and 2, respectively, which have been mentioned more by other researchers. Then, these main complexity factors were developed according to four areas of organization, features, resources, and environment. Also, the identified competency criteria were classified based on four categories of management, knowledge, performance, and behavior. Consequently, the proposed classification structure of project complexities, project manager competencies and the relationships between competency criteria and complexity factors is shown in Fig. 1.

4. Fuzzy Set Theory

Phrases such as "*to some extent*", "*very possible*" and "*slightly clear*" are used often in daily life, representing some degree of uncertainty in human thoughts. The fundamental concepts of fuzzy set theory were introduced for the first time by professor Zadeh (1965) to take into account the vagueness and uncertainty involved in real-world problems. It has been developed for modeling complex systems and decision making processes under inaccurate or ambiguous environments, where there is not enough information to use traditional mathematical models *(Bojadziev and Bojadziev, 2007; Ross, 2010)*. Accordingly, this theory has become a helpful tool for automating human activities based on uncertain information *(Moeinzadeh and Hajfathaliha, 2009)*. This study incorporates fuzzy set theory into project manager selection and project complexity evaluation for objectifying experts' subjective judgments.

Considering the potential capabilities of fuzzy set theory, the systems based on fuzzy logic have been increasingly developed in recent years. Fuzzy logic is derived from the tendency to train computer systems with human expertness. Converting the experts' knowledge about a specific problem into an equation that computers can process is very complicated when it comprises a large number of variables and conditions. Therefore, through formulating these experiences, fuzzy logic will be able to obtain outputs for all input combinations without the clear model of considered problem *(Nguyen and Walker, 2005)*. In fuzzy logic, qualitative attributes are illustrated through linguistic variables that are exhibited qualitatively by linguistic terms and quantitatively by fuzzy sets and their respective membership functions. Linguistic variables are a special type of variables whose values are words and sentences in natural or artificial languages. For instance, the possible values for these variables could be: *very low*, *low*, *medium*, *high*, and *very high (Zadeh, 1975)*.

As mentioned, the main objective of fuzzy logic is to take advantage of the tolerance for inaccuracy, vagueness, and uncertainty to gain robustness, tractability, and low cost solutions *(Zadeh, 1988)*. Fuzzy logic has been applied to many various problems in project management *(Tah and Carr, 2000; Awad and Fayek, 2012; Chao and Hsiao, 2012; Yazdani-Chamzini et al., 2013)*. Hence, it appears potentially beneficial for modeling the complicated tasks of project complexity evaluation and project manager selection that comprise uncertain and inaccurate data in many variables and factors, qualitative as well as quantitative, with likely nonlinear relations.

Fuzzy logic starts with the concept of fuzzy sets. A fuzzy set is a set without a crisp and clearly defined boundary. It can contain elements with only a partial degree of membership. A membership function is a curve that defines how each point in input space is mapped to a membership degree between 0 and 1. If X is the input space and its elements are denoted by x, then fuzzy set $\tilde{A}$ in X is defined as a set of ordered pairs: $\tilde{A} = \{x, \mu_{\tilde{A}}(x) \mid x \in X\}$. $\mu_{\tilde{A}}(x)$ is called the membership function of x in $\tilde{A}$. In fact, the dependency of x on $\tilde{A}$ is true with the membership degree given by $\mu_{\tilde{A}}(x)$. Fuzzy numbers are a special type of fuzzy sets *(Dubois and Prade, 1978)*.

The simplest membership functions of fuzzy numbers are drawn using straight lines. Of these, the simplest is triangular membership function. This membership function is nothing more than a set of three points forming a triangle. Also, trapezoidal membership function has similar features. It has a flat top and is really just a truncated triangle curve. These straight line membership functions have the advantage of simplicity. Triangular and trapezoidal fuzzy numbers are usually used in decision making processes due to their intuitive membership functions *(Kahraman, 2008)*. These numbers show the fuzziness of decision-making data. Trapezoidal Fuzzy Numbers (TFNs) are the most widely used types of fuzzy numbers since they can be handled arithmetically and interpreted intuitively *(Chou et al., 2008)*. Hence, TFNs are used in this research. Given TFN $\tilde{A}_1 = (l, m_1, m_2, u)$; $l \geq 0$, the signed distance of a TFN is defined as *(Kaufmann and Gupta, 1991)*:

$$d(\tilde{A}_1) = \frac{1}{4}(l + m_1 + m_2 + u) \qquad (1)$$

And, the normalization of TFNs is defined as:

$$A_i = \frac{d(\tilde{A}_i)}{\sum_{i=1}^{n} d(\tilde{A}_i)};\ \forall\ i = 1, \ldots, n \qquad (2)$$

where $A_i \in [0, 1]$ and $\sum_{i=1}^{n} A_i = 1$.

In this research, TFNs represent the evaluations of project complexity factors and project manager competency criteria. To select a suitable project manager, TFNs are transformed into crisp real numbers to rank candidate project managers. Four prominent defuzzification methods are generally employed: α-cut, mean of maximal, signed distance, and the center of area. Each method has its own strengths and weaknesses. The center of area and signed distance methods are the simplest and most popular in practice, but considering membership grade, signed distance is superior to the center of area for defuzzifying a fuzzy number. Therefore, the signed distance method is employed in this study to defuzzify TFNs *(Yao and Wu, 2000)*

Tab. 1. Main project manager competency criteria presented in other studies

Competency criteria	Researchers												
	Ahadzie et al. (2008)	Shahhosseini and Sebt (2011)	Lin (2011)	Safarzadegan et al. (2012)	Afshari et al. (2013)	Ahsan et al. (2013)	Othman and Jaafar (2013)	Zhang et al. (2013)	Varajão and Cruz-Cunha (2013)	Ahadzie et al. (2014)	Sadeghi et al. (2014)	Dodangeh et al. (2014)	Afshari (2015)
Planning			✓	✓	✓	✓	✓		✓		✓	✓	✓
Communication	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Compliance			✓	✓		✓			✓				
Education and experience	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓
Coordination		✓	✓	✓	✓	✓	✓		✓		✓	✓	✓
Negotiation		✓	✓	✓		✓	✓	✓	✓		✓		
Leadership and development		✓	✓	✓	✓		✓	✓	✓		✓	✓	✓
Organizing			✓	✓	✓				✓		✓	✓	✓
Trade off			✓	✓	✓	✓	✓		✓			✓	✓
Conformity	✓	✓	✓	✓		✓	✓	✓	✓	✓			
Cognition and control	✓		✓	✓	✓				✓	✓	✓	✓	✓
Adaptation		✓	✓	✓					✓		✓		

Tab. 2. Main project complexity factors presented in other studies

Complexity factors	Researchers												
	Xia and Chan (2012)	Gransberg et al. (2013)	Senescu et al. (2013)	Vidal et al. (2013)	Lessard et al. (2014)	Ramasesh and Browning (2014)	Qureshi and Kang (2015)	Nguyen et al. (2015)	Lu et al. (2015)	Li et al. (2015)	He et al. (2015)	Giezen et al. (2015)	Bosch-Rekveldt et al. (2015)
Schedules	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		
Stakeholders	✓			✓	✓		✓	✓		✓	✓		✓
Laws and regulations					✓		✓	✓		✓	✓		
Technologies	✓	✓	✓	✓				✓	✓	✓	✓		✓
Contractors and suppliers		✓		✓	✓		✓	✓	✓	✓	✓	✓	✓
Contracts								✓		✓			✓
Team			✓	✓	✓		✓		✓	✓	✓		
Information systems				✓			✓		✓	✓	✓		
Objectives				✓			✓		✓				
Requirements					✓			✓					✓
Scope	✓	✓	✓	✓		✓	✓	✓				✓	✓
Geography and climate	✓				✓			✓					

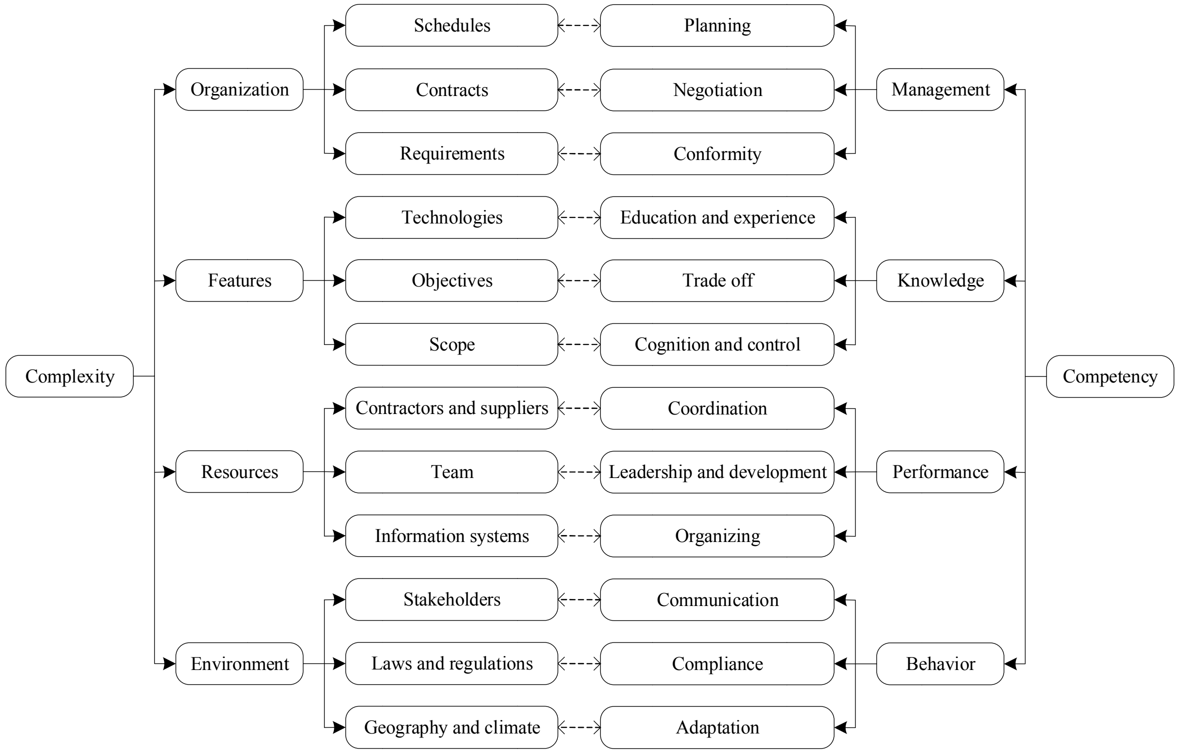

Fig. 1. The proposed classification structure of project manager competency criteria and project complexity factors

5. The Proposed Approach

Multiple Attribute Decision Making (MADM), which constitutes a significant branch of Multi-Criteria Decision Making (MCDM) paradigm, encompasses a number of successive steps leading to some global scores obtained through making a compromise between some different and even conflicting criteria. These global scores, each associated with one of the evaluated alternatives, are utilized to provide the final ranking of alternatives *(Esfahanipour and Davari Ardakani, 2015)*. In most of the economical, industrial, financial, or political decision problems, the evaluation and selection of solution is a typical multiple attribute decision-making problem. In other words, determining the best efficient alternative among many other possible ones, according to decision-makers' preferences, requires one to take several attributes into account. There are many techniques that have been developed to help decision-makers rank alternatives according to many criteria *(Shirinfar and Haleh, 2011)*. Decision-makers tend to evaluate everything based on their own past experience and knowledge, and usually utter estimates using equivocal linguist utterances. In order to unify the experiences, beliefs, and ideas of decision-makers, it is better to transform linguistic estimates into fuzzy numbers. So, decision making in the real world has made it necessary to use fuzzy set theory *(Yousefi Nejad Attari et al., 2012)*.

The new integrated MADM methods can be used for project manager selection problem. However, it should be noted that the main purpose of this study is to provide a specific approach for project manager selection considering the project complexity. Accordingly, in the first step, a comprehensive literature review has been done, and project complexity factors and project manager competency criteria provided in recent years by other researchers,were identified. After an investigation and comprehensive analysis of these competency criteria and complexity factors, the main project manager competency criteria and project complexity factors, mentioned more by other researchers, were introduced. Consequently, the proposed classification structure of project complexities, project manager competencies, and the relationships between competency criteria and complexity factors were presented.

In the second step, we have tried to design and implement a fuzzy group decision making approach to select the best project manager while taking into account the static complexity of construction projects. Since the selection of a suitable project manager is a practical issue and has numerous applications in practice, it has been tried that the proposed technique is as simple as possible, such that the practitioners can easily use it. In this regard, instead of using other MCDM methods which are more complex and more difficult to implement, the fuzzy SAW method has been used in the proposed approach to this research, due to its simplicity, understandability, and ease of implementation.

As it was mentioned in the literature review, many other researchers have also used a variety of decision making techniques for the project manager selection problem. We specifically investigate some of them here. Vainiūnas et al. (2010) introduced a newly developed ranking technique of project managers, based on their multiple experience and technical skills, by applying AHP and TOPSIS. They also presented a real case study that was applied in practice. Highlighting the complexity of the project manager selection process, Kelemenis et al. (2011) proposed a multi-criteria approach based on fuzzy TOPSIS for group decision making. Three new concepts were introduced, namely the relative importance of the decision-makers per criterion, the similarity-proximity degree among the decision-makers, and the veto thresholds. Torfi and Rashidi (2011) performed a case study in which a fuzzy multiple criteria decision making model was used to select the best candidate for the postition of project manager in a large construction firm. The applicants were ranked using AHP, approximate weights of the criteria, and fuzzy TOPSIS.

Shahhosseini and Sebt (2011) presented a fuzzy adaptive decision making model to evaluate and rank the different types of competent construction personnel. Decision making was performed in two stages: a fuzzy AHP for evaluating the competency criteria and an adaptive neuro fuzzy inference system for establishing the competency If-Then rules of the fuzzy inference system. Lin (2011) proposed a decision making model for human resource allocation in remote construction projects by estimating total project cost as the project level risks. He used Delphi and fuzzy AHP process to practically evaluate the proficiency between in-house and local employees, which helps decision-makers to estimate their potential project losses. Zavadskas et al. (2012) developed a multiple criteria assessment model to assess project managers' competence level and their experience to manage different buildings. A set of criteria weights was determined. The AHP, expert judgement, and additive ratio assessment (ARAS) methods were employed.

Afshari et al. (2012) implemented the simple additive weighting method for selecting project manager. It was tried to exploit a systematic methodology in order to determine the hierarchical structure of hiring criteria and sub criteria in multi-criteria decision making model for project manager selection. Chen and Hung (2012) combined the interval linguistic TOPSIS with maximizing deviation method to evaluate the ability of each employee. Based on the importance of project managers' cooperation experiment with other member in the enterprise, this study modified degree centrality to calculate the cooperation capacity of each employee. Project manager was selected by considering employees' ability and their cooperation capacity simultaneously. Varajão and Cruz-Cunha (2013) proposed the joint use of AHP and IPMA competence baseline as a tool for the decision making process of selecting the most suitable manager for construction projects. They constructed a hierarchical structure, comprising the IPMA competence elements.

Chen et al. (2013) examined the general ability, professional ability, and the social network strength of each employee for the purpose of selecting a project manager. Accordingly, interval linguistic TOPSIS was combined with maximizing deviation method to evaluate the general ability of each employee. Sadeghi et al. (2014) presented a construction project manager competency model and an evaluation method which utilizes a goal programming technique to calculate the interval weights of criteria and uses TOPSIS technique with interval weights and judgment data to select the competent project manager. Chaghooshi et al. (2016) proposed the joint use of the fuzzy DEMATEL and fuzzy VIKOR methods for the decision-making process of selecting the most suitable managers for projects. With the opinions of the senior managers based on project management competency model (ICB-IPMA), all the criteria required for the selection were gathered.

The decision making methods that have been often used in previous studies for project manager selection include AHP, fuzzy AHP, TOPSIS, fuzzy TOPSIS, interval linguistic TOPSIS, interval TOPSIS, Adaptive Neuro Fuzzy Inference System (ANFIS), Additive Ratio Assessment (ARAS), maximizing deviation, Goal Programming (GP), fuzzy DEMATEL, fuzzy VIKOR, ANP, Complex Proportional Assessment (COPRAS), and grey relations. In addition, the other multi-criteria decision-making techniques which can be also utilized for the complexity evaluation and project manager selection problem include: fuzzy ANP, ELECTRE, fuzzy ELECTRE, SMART, DEA, MOORA, fuzzy MOORA, MULTIMOORA, SWARA, WASPAS, Entropy, PROMETHEE, fuzzy PROMETHEE, GRA, EVAMIX, and LINMAP. But as mentioned, the fuzzy SAW method has been used in the proposed approach of this research due to its simplicity, understandability, and ease of implementation.

The proposed approach for project manager selection based on the evaluation of project complexity is shown in Fig. 2. Organization's projects (p_i; i = 1, . . ., m) that are at their early stages and available project managers (pm_j; j = 1, . . ., n) are determined in the first step. Also, at this step, a group of experts (e_k; k = 1, . . ., r) with different expertise from various parts of the organization are selected to form a decision making group. It is clear that these experts have distinct levels of knowledge and experience; therefore, their importance weights are different and should be defined ($\tilde{w}_k$; k = 1, . . ., r) through interviewing some other senior managers of the organization. These importance weights are expressed by linguistic terms. The fuzzy importance weights of decision-makers are defuzzified ($d(\tilde{w}_k)$; k = 1, . . ., r) by using the signed distance defuzzification equation shown in Eq. 1. Then, the crisp values of the experts' importance weights are normalized (w_k; k = 1, . . ., r) using Eq. 2.

The identification of project complexity factors (f_l; l = 1, . . ., q) and project manager competency criteria (c_l; l = 1, . . ., q) are the first tasks of the decision making group members. Experts also determine the relationships between these complexity factors and competency criteria. In other words, it must be specified that any project complexity factor is associated with what type of project manager competency. For instance, the *schedules* complexity of projects is related to the *planning* competency of project managers. Due to uncertainty and ambiguity in expressing the exact values of complexity factors and competency criteria, fuzzy set theory is used. In this regard, linguistic terms and their corresponding fuzzy numbers are defined in the first step. For example, the values of complexity factors can be expressed by five linguistic terms: *very low*, *low*, *medium*, *high*, and *very high*, and trapezoidal fuzzy numbers can be used for these linguistic terms.

The second step involves the evaluation of project complexity factors. In this step, at first, one of the organization's projects is considered (p_i). Then, each of the considered project's complexity factors is evaluated by the organization experts ($\tilde{f}_{ilk}$; l = 1, . . ., q; k = 1, . . ., r). They express their opinions about the values of complexity factors using linguistic terms, and in order to be able to perform mathematical calculations on these linguistic terms, fuzzy numbers corresponding with them are used. Next, based on the experts' importance weights, the weighted average of experts' individual evaluations of each complexity factor is calculated as $\tilde{f}_{il} = \sum_{k=1}^{r} w_k \times \tilde{f}_{ilk}$; $\forall$ l = 1, . . ., q (Eq. 3). These quantities are the final fuzzy values of the considered project's complexity factors ($\tilde{f}_{il}$; l = 1, . . ., q).

As we said, the relationships between project complexity factors and project manager competency criteria are determined in the first step. So, the final fuzzy value of each complexity factor can be used as the fuzzy importance weight of corresponding competency criterion ($\tilde{f}_{il} = \tilde{w}_{il}$; l = 1, . . ., q). Because if the complexity degree of a factor in a project is high, then the related competency criterion for project manager will be of high importance too. The fuzzy importance weights of competency criteria are defuzzified ($d(\tilde{w}_{il})$; l = 1, . . ., q) by using the signed distance defuzzification equation shown in Eq. 1. Then, the crisp values of the competency criteria importance weights are normalized (w_{il}; l = 1, . . ., q) using Eq. 2.

In the third step, the evaluation of project managers' competencies and the selection of a suitable project manager will be done. In this stage, at first, one of the available project managers is considered (pm_j). Then, each of the considered project manager's competency criteria is evaluated by the organization experts ($\tilde{c}_{jlk}$; l = 1, . . ., q; k = 1, . . ., r). Like the previous step, they express their opinions about the values of competency criteria using linguistic terms; in order to be able to perform mathematical calculations on these linguistic terms, fuzzy numbers corresponding with them are used. Next, based on the experts' importance weights, the weighted average of experts' individual evaluations of each competency criterion is calculated as $\tilde{c}_{jl} = \sum_{k=1}^{r} w_k \times \tilde{c}_{jlk}$; $\forall$ l = 1, . . ., q (Eq. 4). These quantities are the final fuzzy values of the considered project manager's competency criteria ($\tilde{c}_{jl}$; l = 1, . . ., q).

From the previous stage, the crisp values of complexity factors are used as the importance weights of competency criteria (w_{il}; l = 1, . . ., q). Therefore, based on these competency criteria importance weights, the weighted average of the final fuzzy values of the considered project manager's competency criteria is calculated as $\tilde{c}_j = \sum_{l=1}^{q} w_{il} \times \tilde{c}_{jl}$ (Eq. 5). This quantity is the total fuzzy competency score of the considered project manager ($\tilde{c}_j$). Until the total fuzzy competency scores of all project managers are evaluated ($\tilde{c}_j$; $j = 1, \ldots, n$), the third step will be continued. These fuzzy competency scores are defuzzified ($d(\tilde{c}_j)$; $j = 1, \ldots, n$) by using the signed distance defuzzification equation shown in Eq. 1. Then, based on these crisp outputs of the project managers' competency evaluation stage, the project managers are compared and ranked. According to this ranking, the best project manager is identified and allocated to the considered project. After that, another project will be considered and the above steps should be repeated for it.

If a project manager is evaluated suitable for more than one project, then the project manager should be allocated to the project that for whose most complex factor be in direct correlation with the higher corresponding competency of the selected project manager. For instance, consider that after the above steps, pm_1 has the highest rank for p_1 and also for p_2. The most complex factor of p_1 is *technologies*, and the most complex factor of p_2 is *stakeholders*. According to Fig. 1, the complexity factor of technologies is related to the competency criterion of *education and experience* and the complexity factor of stakeholders is related to the competency criterion of *communication*. pm_1 is rated higher in the competency criterion of education and experience than the competency criterion of communication. Therefore, pm_1 is a better option for p_1 and will be allocated to it. The steps mentioned above will continue until one project manager is assigned to each project. At the end, the complexity factors' levels of each project should be compared with the competency criteria levels of the project manager allocated to it. If the level of a competency criterion is lower than the level of its related complexity factor, then this criterion should be improved to increase the competency level of the selected project manager. For example, consider that pm_1 was allocated to p_1. The *contracts* complexity factor of p_1 was evaluated *very high*, but the *negotiation* competency criterion of pm_1, which is related to the contracts complexity factor, was evaluated *medium*. Hence, the organization must plan to enhance the negotiation competency of pm_1, which can be done through holding some training courses.

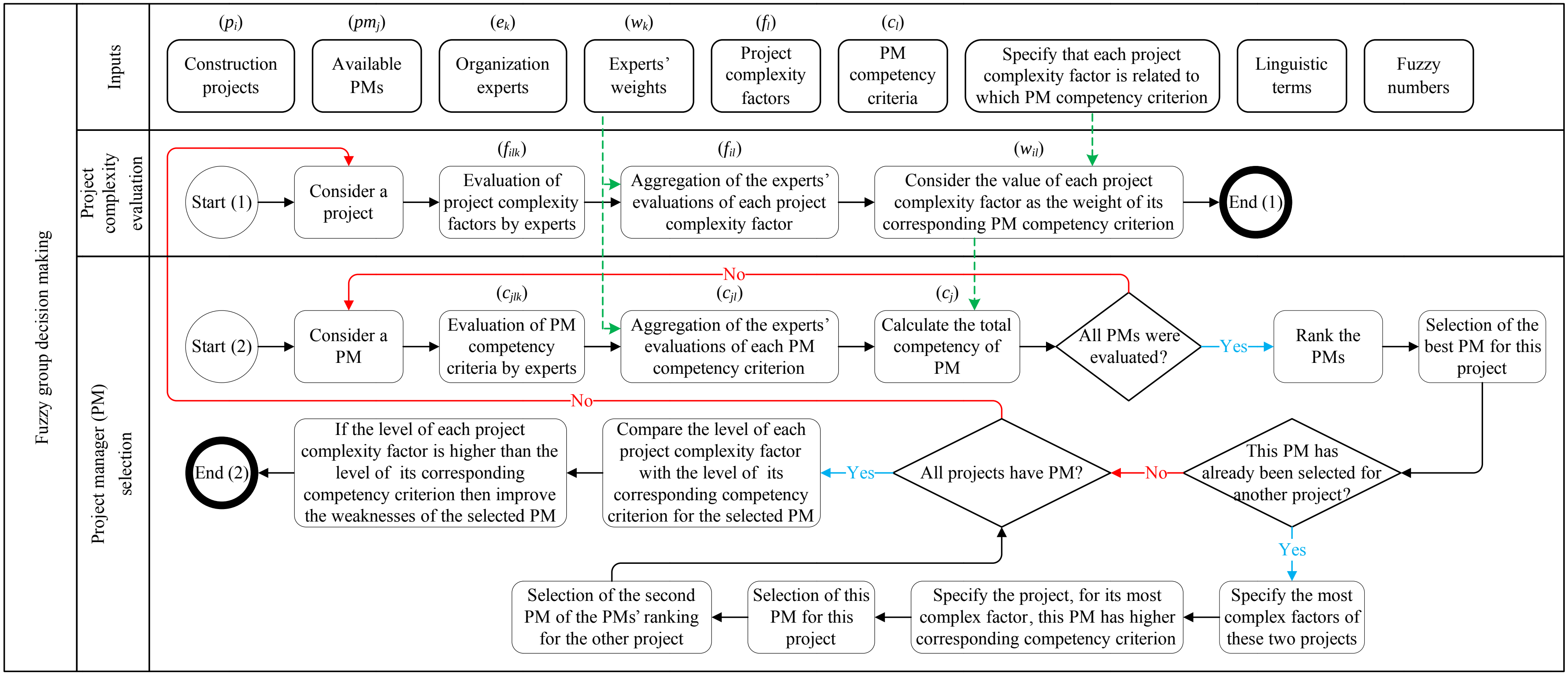

Fig. 2. The proposed approach for project manager selection considering the project complexity

6. Case Study

As previously mentioned, the selection of a suitable project manager is a practical issue and one of the main challenges for project-based organizations. Therefore, in this study, it was decided that to prove the efficiency and performance of the proposed method, we execute it in a practical case study for a construction project manager evaluation. In fact, the validation of the proposed approach was inspected by using a real case study of project manager selection. For this purpose, this methodology has been implemented in one of the biggest construction companies in Iran in order to choose the right persons for project manager positions considering the static complexity of projects.

Our case is an Iranian enterprise with its 39 subsidiaries, active in the development and construction of thermal power plants under EPC scheme (Engineering, Procurement, and Construction). Till now, they have finished about 100 projects, worth more than 30 billion euros. With over 56000 Megawatt of commissioned, under construction and prospect power plant projects, constituting 90 percent of Iran's installed power plants capacity. The company is the first and largest general contractor of power plants in the Middle East and West Asia. They are also active in international markets; for instance, we can mention various projects in Iraq, Syria, Turkey, Oman, and Lebanon. Recently, the company faces with some problems in achieving the objectives of its projects. Some projects do not progress according to their schedules, cost more than their approved budget, and finished with a large number of defects. According to the project management experts of the company, complexity can be one of the main reasons for their projects failures and allocating appropriate project managers by considering project complexity can significantly reduce these problems.

Therefore, three projects (p_1, p_2, p_3) of the company's project portfolio that are at their early stages and more complex than other projects were selected by the company's experts to evaluate their complexity and allocate three suitable project managers to them using the proposed approach. All three projects are combined with cycle power plants. The first one (p_1) is the biggest power plant in Iran, comprising 12 gas units and 6 steam units, and it produces a total of about 2880 Megawatt of power. It is erected on an area of 193 hectares of land in the southeast of Tehran. The second one (p_2) includes the construction of 3000 Megawatt power plant in Iraq and is located in Basra suburb. This great thermal power plant is also equipped with 12 gas and 6 steam turbines. The company is responsible for the engineering, procurement and installation of equipment. The last one (p_3) is located in a land measuring 4.1 hectares in the north of Qeshm Island. The project scope includes electricity and water generation, consisting of two gas turbo generators, two heat recovery boilers, and four water sweetening systems, each with the capacity of 4500 cubic meters of fresh water per diem. Also, four available project managers (pm_1, pm_2, pm_3, pm_4) were considered by the company's experts in order to evaluate their competencies and allocate three of them to these three projects.

Due to the fuzzy nature of project manager selection and project complexity evaluation problems, and uncertainty and ambiguity in expressing the exact values of complexity factors and competency criteria, fuzzy set theory was used. In this regard, linguistic terms and their corresponding fuzzy numbers were defined in the first step. In fuzzy set theory, linguistic terms should be transformed into fuzzy numbers. A scale of one to five is often used to convert linguistic terms into fuzzy numbers *(Chen and Hwang, 1992)*, that was also used in this research for the importance weights of decision-makers and the values of complexity factors and competency criteria. The importance weights of individual experts, the complexity of projects versus different factors, and the competency of project managers versus diverse criteria were considered as linguistic terms. Trapezoidal fuzzy numbers were used for these linguistic terms because they could be easily used and interpreted.

In the first step of the proposed approach, a group of decision-makers consisting of five experts (e_k; k = 1, . . ., 5) with different expertise from various parts of the company, including procurement, planning, engineering, financial, and quality management, were selected to form a decision making group. These experts have distinct levels of knowledge and experience; therefore, their importance weights are different and were defined ($\tilde{w}_k$; k = 1, . . ., 5) through interviewing some other senior managers of the company. The fuzzy importance weights of decision-makers were defuzzified ($d(\tilde{w}_k)$; k = 1, . . ., 5) by using the signed distance defuzzification equation shown in Eq. 1. Then, the crisp values of the experts' importance weights were normalized (w_k; k = 1, . . ., 5) using Eq. 2.

According to the opinions of five experts about the main project complexity factors presented in

Tab. 2 and based on the inherent characteristics of these thermal power plant projects, ten factors of complexity were identified in the considered projects (f_l; l = 1, . . ., 10) as listed in Tab. 3. Also, based on the experts' opinions about the main competency criteria of project managers presented in Tab. 1, ten competency criteria, in association with the selected complexity factors, were identified for the available project managers (c_l; l = 1, . . ., 10) as listed in Tab. 3. The decision making group members also specified that any project complexity factor is associated with what type of project manager competency. They determined the relationships between the identified complexity factors and competency criteria as the relationships shown in Fig. 1. For instance, the *planning* competency of project managers is related to the *schedules* complexity in these three projects.

Tab. 3. Main identified project manager competency criteria and project complexity factors

Complexity factors		Competency criteria	
f_1	Schedules	c_1	Planning
f_2	Requirements	c_2	Conformity
f_3	Technologies	c_3	Education and experience
f_4	Scope	c_4	Cognition and control
f_5	Contractors and suppliers	c_5	Coordination
f_6	Team	c_6	Leadership and development
f_7	Information systems	c_7	Organizing
f_8	Stakeholders	c_8	Communication
f_9	Laws and regulations	c_9	Compliance
f_{10}	Geography and climate	c_{10}	Adaptation

In the second step, at first, one of the organization's projects was considered (p_1). Then, each of the considered project's complexity factors was evaluated by the organization experts ($\tilde{f}_{1lk}$; l = 1, . . ., 10; k = 1, . . ., 5). The assessments of complexity factors were scored as linguistic terms ranging from *very low* to *very high*, based on the experts' estimations. As previously mentioned, for the designed fuzzy group decision making system, trapezoidal fuzzy numbers were used to specify the membership functions of the linguistic variables. Next, based on the experts' importance weights, the weighted average of experts' individual evaluations of each complexity factor was calculated as Eq. 3. These quantities are the final fuzzy values of the considered project's complexity factors ($\tilde{f}_{1l}$; l = 1, . . ., 10).

As we said, the relationships between project complexity factors and project manager competency criteria were determined in the first step. So, the final fuzzy value of each complexity factor was used as the fuzzy importance weight of corresponding competency criterion ($\tilde{f}_{1l} = \tilde{w}_{1l}$; l = 1, . . ., 10). The fuzzy importance weights of competency criteria were defuzzified ($d(\tilde{w}_{1l})$; l = 1, . . ., 10) by using the signed distance defuzzification equation shown in Eq. 1. Then, the crisp values of the competency criteria importance weights were normalized (w_{1l}; l = 1, . . ., 10) using Eq. 2. At the third stage, at first, one of the available project managers was considered (pm_1). Then, each of the considered project manager's competency criteria was evaluated by the organization experts ($\tilde{c}_{1lk}$; l = 1, . . ., 10; k = 1, . . ., 5). Like the previous step, they expressed their opinions about the values of competency criteria using linguistic terms ranging from *very poor* to *very good*, and in order to be able to perform mathematical calculations on these linguistic terms, trapezoidal fuzzy numbers corresponding with them were used. Next, based on the experts' importance weights, the weighted average of experts' individual evaluations of each competency criterion was calculated as Eq. 4. These quantities are the final fuzzy values of the considered project manager's competency criteria ($\tilde{c}_{1l}$; l = 1, . . ., 10).

From the previous stage, the crisp values of complexity factors were used as the importance weights of competency criteria (w_{1l}; l = 1, . . ., 10). Therefore, based on these competency criteria importance weights, the weighted average of the final fuzzy values of the considered project manager's competency criteria was calculated as Eq. 5. This quantity is the total fuzzy competency score of the considered project manager ($\tilde{c}_1$). Until the total fuzzy competency scores of all project managers have been evaluated ($\tilde{c}_j$; j = 1, . . ., 4), the third step continued its progress. Then, these fuzzy competency scores were defuzzified ($d(\tilde{c}_j)$: j = 1, . . ., 4) by using the signed distance defuzzification equation shown in Eq. 1. Finally, based on these crisp outputs of the project managers' competency evaluation stage, the project managers were compared and ranked. According to this ranking, the best project manager (pm_4) was identified and allocated to the considered project. After that, another project (p_2) was considered and the above steps were repeated for it. After the above steps, pm_4 has the highest rank for p_1 and also for p_2. The most complex factor of p_1 is *scope* (0.79) and the most complex factor of p_2 is *contractors and suppliers* (0.86). According to Fig. 1, the complexity factor of scope is related to the competency criterion of *cognition and control* and the complexity factor of contractors and suppliers is related to the competency criterion of *coordination*. pm_4 was rated higher in the competency criterion of cognition and control (0.88) than the competency criterion of coordination (0.37). Therefore, pm_4 was a better option for p_1 and was allocated to it. The steps mentioned above continued until pm_2 was assigned to p_2 and pm_1 to p_3.

At the end, the complexity factors' levels of each project were compared with the competency criteria levels of the project manager allocated to it. The levels of some competency criteria were lower than the levels of their related complexity factors, so these criteria were improved to increase the competency levels of the selected project manager. For example, pm_4 was allocated to p_1. The *schedules* complexity factor of p_1 was evaluated 0.73, but the *planning* competency criterion of pm_4, which is related to the schedules complexity factor, was evaluated *0.50*. Hence, the company planned to enhance the planning competency of pm_4, which was done through holding some training courses. After applying the designed framework in a number of company's power plant projects, the feedbacks reveal that the model is quite reliable in selecting the suitable project manager and can ameliorate the efficiency of decision making process. The obtained results illustrate the applicability and performance of the proposed competency model and evaluation method in practical situations. The usefulness of the proposed approach is also approved by the company's experts.

7. Conclusion

Project management is a critical task that needs the best people in charge. Assigning the most competent project manager is a complicated subject, because there are many issues to be considered. Also recently, managing complexity has become an important aspect of project management, which should be considered carefully. In this regard, this study investigates the decision of project manager selection for mega construction projects with the consideration of projects' static complexity. The methodology and decision making procedure developed in this research are based on a fuzzy group decision making approach. The use of fuzzy set theory involves the application of fuzzy numbers to represent the experts' opinions when expressing project manager competency criteria or estimating the values of project complexity factors, and to deal with the uncertainty and ambiguity of human language. Compared with previous studies, this study provides several contributions in project manager competency measurement methodology. It has made a distinguished contribution to knowledge by adopting a comprehensive approach, fuzzy group decision making system, for project manager selection considering the project complexity.

This research does not limit project manager competency evaluation to project managers' ranking. Instead, it includes identifying the competency criteria of project managers and the complexity factors of projects. In a practical sense and as a direct result of this paper, a set of twelve specific project manager competency criteria and associated project complexity factors has been presented. These twelve indicators represent the general criteria for evaluating project managers' proficiency based on projects' actual complexities. Moreover, the proposed approach allocates a project manager in several distinct steps. At first, project complexity factors and then project manager competency criteria are evaluated using a fuzzy group decision making system. This study provides the ability to control project complexity by selecting a suitable project manager. In this regard, an allocated project manager must meet an acceptable competency level in each complexity factor. Otherwise, related proficiency conditions will be enhanced or improved to increase project manager competency levels. Accordingly, this feature makes it possible to align project manager selection decisions with project context. Organization's decision-makers can also use the information obtained from the evaluated static complexity of their mega construction projects to improve other managerial decisions, such as choosing more suitable organization and strategy arrangements for project execution. Furthermore, this obtained knowledge about project complexity and project manager competency is then captured and saved into the system for future use.

However, the expected advantages of the developed approach are very much a learning process depending on various factors such as the selection of complexity factors, competency criteria and the parameters of fuzzy group decision making system such as linguistic terms and fuzzy numbers. The proposed process should be repeated and reviewed continuously during different project lifecycle phases to be aware of the changes in project complexity and project manager competency. Therefore, further studies can develop a computer software which will evaluate static complexity and project manager competency continuously for real-time control and regular improvements in the management of mega construction projects. A future step to this paper could be the use of other MADM methods for the complexity evaluation and project manager selection problem, such as fuzzy ANP, ELECTRE, fuzzy ELECTRE, SMART, DEA, MOORA, fuzzy MOORA, MULTIMOORA, SWARA, WASPAS, Entropy, PROMETHEE, fuzzy PROMETHEE, GRA, EVAMIX, and LINMAP, or their comparison with the proposed approach. For future research, we can develop and apply the presented evaluation method of this paper to analyze project manager selection problems in other companies and other types of construction projects to further demonstrate the applicability of the proposed model. Future studies can also describe the application of other approaches, such as fuzzy inference systems for project complexity evaluation and project manager selection.

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