A risk-cost optimization model for selecting human resources in construction projects

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Received: 18 July 2019 / Accepted: 24 October 2019 / Published online: 31 October 2019
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Abstract

One of the solutions for the reduction of the risk of human resource selection in construction projects is to employ specialized people, but this approach imposes tremendous costs because productive people have a high cost of employment. This study provides a model for employing human resources in construction projects with the risk-cost optimization approach. This work, through a review of previous studies, identified several risks in human resource selection that were prioritized in this study by using a questionnaire. The risk-cost rate of each candidate was determined using one of the multi-criteria decision making methods named additive-veto. Finally, the optimization model was developed using the zero-one non-linear programming approach. One of the innovations of this research was to optimize the risk of employees around the organization's tolerable level of risk rather than reducing risk. The results showed that the selection of human resources based on the model could reduce to a large extent the risk-cost rate.

Keywords Human resource management · Selection · MCDM · Optimization · Zero-one non-linear programming

1 Introduction

The construction is one of the industries with a significant impact on the economy of each country [1]. Therefore, increasing the productivity of the construction industry can, directly and indirectly, improve the economic situation of a country. However, the key question is how the construction industry can increase its productivity.

The construction industry is one that depends on the project performance. The performance of each project is influenced by various economic, political, social, psychological, and religious parameters. It indicates that all of these cases originate from either human resources in the project or indirect involvement of human resources [2]. Therefore, focusing on improving the productivity of human resources can influence other areas considerably and it seems managing human resources is one of the

most effective steps in increasing the probability of successful construction projects [3]. Cho et al. [4] believe that focus on human resource management has a significant impact on cost optimization and increased productivity and quality in the project. Although active companies in the construction industry have found that their most important asset in the 21st century is to have access to an efficient human resources management system [5], the construction industry, due to the complexity and temporal nature of the projects, faces challenges to implement the effective human resources management [6]. Now, the question is how the productivity of human resources can be increased.

To answer the earlier question, the term human resource management and its related activities should be defined clearly. Various definitions have been made by previous researchers, but one of the most comprehensive

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definitions by PMBOK is this: “project human resource management involves organizing and managing a project team” [7]. PMBOK defines a project team consisting of a combination of appropriate people with the roles and responsibilities assigned to them who have gathered together for the project [7]. Activities such as selection, recruitment, training, conduction and guidance, and control of individuals in the organization and project are in the field of human resource management [8]. Although all human resource management processes are of particular importance, the selection of productive force for projects is one of the leading steps in the HRM process as well as one of the main decisions of project managers, which can have much impact not only on the project success but also on the company responsible for the project [9]. The correct and principled selection of the workforce ultimately leads to the creation of a coordinated and productive team, contributing to achieving the desired goals of the project and stakeholders. Choosing a strong and productive project team to carry out the projects is one of the significant topics in construction projects.

In general, when choosing the higher-skilled individuals for a project, the capability and reliability of the project team will increase; in other words, well-educated and experienced people are less likely to make a mistake and consequently the risk of project failure because of human resources' error is low. Since the selection of human resources can impact on the probability of projects' success, the risk of human resource selection is defined as the quality of selected individuals. The risk of human resource selection is low when selected people are expert, on the contrary, the level of risk is high when the selected people are younger or less experienced. Project managers are eager to minimize the risk of running a project with the least cost. The selection of the human resources for a project is an optimization issue because less cost for a project team can in many cases lead to hiring lower-skilled individuals and consequently raising the risk of human resource selection. On the contrary, the formation of a team with the lowest risk causes that the cost constraints in the project face major challenges. In general, the use of MCDM and decision support systems are essential for the selection of human resources [10].

Although various studies have been done on the selection of project human resources by previous researchers (a list of these studies is available in the article published by Behzadian et al. [11]), this survey intends to present a hybrid model to select human resources based on the optimization of risk and cost. In order to determine the inputs of the model, the risks of human resource selection, as well as cost-imposing parameters for the project team, are identified first. Secondly, the risk rate and cost of each candidate is measured using one of the new MCDM

methods. The MCDM method is used whenever the problem deals with several alternatives and criteria [12]. One of the MCDM methods has been chosen called additive-veto. The additive-veto is a compensatory method in the category of MCDM methods provided by De Almeida [13]. In the last step, the proposed model should decide to select a candidate for participation in the project team or not. Since this decision is an optimization problem and it should be considered the different decision-makers' views, the multiple objective decision-making approach is applied [14]. When the objective function is non-linear and the aim of optimization is the selection of one participant from a pool of candidates, a zero-one non-linear programming model is used [15]. Given that the proposed model is a combination of decision-making and optimization tools and considers different parameters in assessing the risk-cost of individuals in order to select them in the project team, it will have the necessary innovation compared to previous research. In addition, the proposed model has the capability to consider qualified people's opinions during the process of selecting project human resources and it can be adopted with the conditions of the construction industry in each country. Therefore, it can be replaced by traditional selection method of human resource selection in the construction projects, and ultimately leads not only to better management of the project team but also can have a significant impact on the time and cost of the project.

This study will proceed as follows; firstly, previous research has been reviewed and after this, the research methodology was presented. According to the research methodology, the proposed model has been described in detail. In order to better understand the model, a case study has been offered in the next section. Finally, conclusions and suggestions have been presented.

2 Literature review

Many researchers have conducted different studies in the field of HRM. Tabassi and Bakar [16] reported that the productivity of a company or project is strongly associated with the project team or its human resources and its strategies. Therefore, a strong project management team is the most valuable asset of construction companies. Gomar et al. [17] developed a model for optimizing the allocation of the multiskilled workforce to the construction projects. They performed their model in different scenarios and observed the benefits of their models. Shahhosseini and Sebt [18] presented a model for selecting a productive team. In this model, the project team (human resources) is divided into four categories: 1- Project Manager 2- Engineer 3- Technician 4- Workers. Then, the competency

benchmark model has been developed for each of these categories. The decision is made in two steps: (1) an analysis process for the Fuzzy Analytic Hierarchy Process (AHP) to assess competency criteria. (2) A Neuro-Fuzzy Inference System (ANFIS) for organizing job-competency in the fuzzy inference system (FIS). Lee et al. [19] focuses on developing a competency model for a team of construction projects and project control teams that have a vital responsibility in building companies and provides a framework for developing human resources, including employment, training, performance assessment and improved ability of organizations. A multi-objective mixed-integer programming model was presented by Florez et al. [20] to maximize labor stability. They addressed the multimode resource-constrained project scheduling problem with respect to social sustainability. Starkey et al. [21] proposed an optimization model to solve the management of workforces in large utility projects. Their model was developed based on fuzzy type-2 and developing fuzzy logic.

Lai et al. [22] stated that HRM activities in projects include employment and selection practices, rewards and incentive measures, safety education, communication and feedback, employee participation and management commitment, performance assessment, and welfare benefits. Gilan et al. [23] presented a model based on the perceptual computer (PER-C) and the linguistic weighted average for selecting human resources or project teams in accordance with competency. Phua [24] examined the effects of cultural differences among human resources employed in the construction industry. Their findings, based on the distribution of the questionnaire among those active in the Hong Kong and Australian construction industry, showed that cultural differences have a huge impact on human resource management. Gao and Low [25] explored the solutions that Toyota Company has been using for its HRM and assessed its ability to implement in Chinese construction companies. They used the semi-structured interview method to conduct their research. Plaskoff and Plaskoff [26] talked about changing the attitudes of organizations from traditional to new resource management. They explained that due to the fact that the work environment has changed dramatically, there should be good choices for HRM techniques. Čančer et al. [27], presented a decision-making system for evaluating human resources. They used a factor analysis method to identify the proper classification of parameters effective in the process of evaluating and then assessed human resources. Tooranloo et al. [28] investigated the factors affecting human resource concepts with a sustainability approach. They categorized the effective parameters at the level of sustainability of human resources in organizations into three categories: economic, social, and environmental; they used the Fuzzy-based models of AHP and Fuzzy

Type-2 DEMATEL to prioritize the criteria. Kim et al. [29] investigated applied a system dynamic approach to survey the causes and effects of shortages in skilled labor in the construction industry. They developed five scenarios to investigate the impacts of the skilled labor shortage in the, for example, labor wages, cost overrun, etc.

According to a review of studies on the human resources and the project team in the construction projects, it became clear that several studies have been done to improve the conditions in the construction projects, but the developed studies in the construction industry are much lower compared to other industries. By examining and following up studies on the HRM and the human resource selection models in the construction projects, problems and deficiencies are well documented. Some of these problems include poor HRM, the use of old methods for selecting the project team, limited methods to be used in teamwork of projects, low productivity in the construction industry compared to other industries, low attention to more recently sciences, such as risk management in the construction industry and the selection of human resources.

3 Methodology

This is applied research in terms of the objective and the library study in terms of data collection methodology based on field research. In a general classification, the executive steps of this study are as shown in Fig. 1:

As shown in the flowchart above, the research process is divided into two general categories. The first category involves identifying the parameters needed to assess the risk-cost of human resources required by the project, and the second is to develop an optimization model and select the appropriate personnel among the existing ones.

The model is general and it can be applied in each situation with some considerations. As discussed, the activities in the first category of research were mostly based on previous studies to detect and extract criteria effective in determining the risk and cost of human resources. To adopt the identified criteria with the situation of each place, distributing a questionnaire between statistical populations is unavoidable. By using the questionnaire each user will be able to apply the model with your concerns. After distributing and collecting questionnaires, various statistical analyses to determine the priority of the identified criteria should be done. The result of this section which is the ranking of risk and cost criteria applied in the process of human resource selection is adopted with the conditions of users. The results of this study which were applied in the Iranian industry are described in detail in the following section. One of the most important analyses

Fig. 1 Executive steps of proposed model

used in this section is to test the normal distribution of the data, followed by the use of parametric or nonparametric tests (according to the normal distribution of data).

The second part of the study included developing an optimization model to select appropriate personnel with the risk-cost optimization approach based on the results of the first part. Specifically, according to the identified and prioritized criteria (outputs of questionnaires) and using the additive-veto decision-making method, the level of risk-cost of candidates was determined and finally the best option among volunteers will be chosen using the zero–one non-linear programming method.

4 Proposed model

According to the explained descriptions in the earlier section, the proposed model was divided into two main parts. The following steps described these two sections in detail.

4.1 Criteria identification

4.1.1 Identification of criteria using previous studies

Considering that the purpose of the present research is to select the human resources needed for the project based

on risk-cost, therefore, the identification of risk and cost criteria is considered.

As described in the introduction section, the risk of human resource selection means the level of expertise and experience of candidates. Each criterion that can affect the level of expertise and experience of workforces can be defined as a risk. Several criteria such as coordination skills, experience, knowledge, communication, accountability, etc. are some examples of risk. For gathering the human resources risks in construction projects, 44 references were studied. In this study, 52 risks related to human resources in the construction projects were extracted. Since several criteria are not suitable for the selection model, they were declined based on the frequency distribution of each criterion among the studied references to 21 criteria that were more important. In other words, the authors remained those criteria in the list that they repeated more than one reference. These criteria are presented in Table 1:

The number of cost criteria compared to risk criteria were less. Finally, seven criteria were derived from articles and resources for use in the second part of the questionnaire, which is presented in Table 2 along with their references. It should be noted that candidates are given a score on the basis of an assessment performed by the cost criteria and multiplied by a base salary, which defines for each occupational position of the organization, and the cost per person is calculated per month.

Table 1 Identified risks

No.	Risks	References
1	Coordination skills, communication and project leadership	[30–35]
2	Lack of sufficient experience in the field of project	[33, 34, 36–40]
3	Poor planning and decision making process	[31, 38, 41, 42]
4	Low quality in technical skill, performance and workmanship	[33, 43–45]
5	Low operational productivity	[34, 41, 46]
6	Technical knowledge and qualifications	[30, 33, 35, 39, 42, 44, 47]
7	Management ability and attitude	[31, 32, 48, 49]
8	Inadequate training of human resources	[33, 37, 38, 45]
9	Not taking care of teamwork and lack of morale and motivation	[33, 35, 39, 50]
10	Responsibility and distribution of risk when needed	[36, 43, 51]
11	Unavailability of the workforce	[34, 48, 52]
12	Failure to observe safety precautions	[33, 35, 37, 38, 53–55]
13	Flexibility when sudden and unpredictable changes in project	[34, 39, 50]
14	Incorrect estimates of time, cost and resources	[31, 50]
15	Human resources protests and interrupting the works	[31, 49, 52]
16	Ability to estimate predictable conditions and problems	[37, 48, 56]
17	Similar work experience	[33–35]
18	Ability to obtain project approvals and licenses required	[31, 47]
19	Ability to organize and coordinate the risk	[31, 33]
20	Falling, hurt and injury during the project	[39, 54]
21	Inability to understand the goals and importance of the project	[31, 39, 41]

Table 2 Identified criteria for cost

No.	Cost criteria	References
1	Management ability	[39, 43, 57–59]
2	Experience	[39, 58–60]
3	Project budget	[39, 57–59]
4	Productivity	[39, 43, 57, 58]
5	Ability to estimate the conditions correctly	[39, 43, 57–59]
6	Complexity and importance of the project	[39, 43, 57–59]
7	Knowledge and awareness of the project	[39, 43, 57–59]

4.1.2 Questionnaire design

In order to adapt and prioritize the identified criteria with the concerns of users, a questionnaire is needed. This approach helps to generalize the proposed model since the results of the questionnaire can be adopted with the condition of each company. In other words, some risks which are highlighted for example, in the Iranian construction industry, may not be important in the European construction industry. Therefore, distributing, collecting and analyzing questionnaires will be able to reveal the most important criteria in each circumstance. The questionnaire was arranged in three sections. The first part included the introduction of demographics for respondents in order to provide more accurate answers, and the next two sections included an assessment of 21 risk factors and 7 cost

criteria. The five-point Likert scale (1: the least score and 9: highest scores) were used to get feedback from respondents. In order to answer the questionnaire and show how the analysis and results will be derived, the statistical population of managers in the construction industry in Tehran as the capital of Iran was considered. Since the exact number of these individuals is not known, therefore, according to the Cochran formula [61] for infinite societies, the sample size was determined 153 at an error level of 5% and the questionnaire was distributed among the individuals.

The methods of distributing the questionnaire in this study were through face-to-face, email and posting through social networks for the subject. The percentage of receiving the questionnaire was 100% on face-to-face visits (the questionnaire was distributed among 38 people), but this rate was 55% by email and social networks (a questionnaire distributed among 212 people). Ultimately 153 questionnaires were collected.

4.1.3 Analyzing the questionnaire

In order to use the results of the questionnaire, various statistical analyses should be applied to the results. Further analyses are described.

- *Questionnaire reliability*: questionnaire reliability is one of the most important issues in the collection of information. Cronbach's alpha coefficient was used to calcu-

late reliability. This coefficient was calculated 0.708 for risk and 0.850 for cost criteria. Given that both values are larger than 0.7, the reliability of the questionnaire is confirmed [62].

- **Questionnaire validity:** According to the research topic, a questionnaire was first prepared and then a number of experts and technicians were selected to evaluate the validity, which was approved after the correction of some of their questions, and finally the questionnaire validity was confirmed.
- **Descriptive analysis of the questionnaire:** The respondents of the questionnaires were between the ages of 30 and 60 years, whose number based on experience and expertise is shown in Fig. 2.
- **Quantitative analysis of the questionnaire:** The main objective of the quantitative analysis of the questionnaire is to determine the weights of each of the identified risk-cost criteria. In order to quantitatively analyze the questionnaire in the first step, the questionnaire is considered normal or abnormal status. The Kolmogorov–Smirnov test was used for considering the normality of data [63] and the results showed the data weren't normal so the nonparametric test named Friedman was applied [64]. The results of the criteria weights are presented based on the score obtained by each criterion in the Friedman test in Table 3 (weights related to risk criteria for the human resource) and Table 4 (weights related to cost criteria for the human resource) after normalizing with linear normalization method.

According to the data tabulated in Table 3 three criteria including Failure to observe safety precautions, responsibility, and distribution of risk when needed, and poor

planning and decision-making process are the most important risk with respect to the respondents' opinions. In other words, respondents believed that the ability of these criteria is stronger to reduce the performance of human resources.

According to the data tabulated in Table 4 two criteria including project budget, and productivity are the most effective cost parameters in the cost of human resources with respect to the respondents' opinions.

4.2 Optimization model

4.2.1 Developing the objective function

The first part of the present model is defining the objective function with its constraints. The proposed objective function is the optimal sum of the two risk-cost parameters for the selected candidates, Eq. 1 shows the proposed objective function. The logic behind the objective function is as follows:

$$\begin{aligned} \text{Min } Z &= W_r \left(1 - \frac{\sum_{j=1}^m \sum_{i=1}^n X_{ij} R_{ij}}{R_{\text{tolerable}}} \right)^2 + W_c \left(\frac{\sum_{j=1}^m \sum_{i=1}^n X_{ij} C_{ij} I_j t_j}{C_T} \right)^2 \\ \text{Subject to} \\ W_r + W_c &= 1 \\ \sum_{j=1}^m \sum_{i=1}^n X_{ij} C_{ij} I_j t_j &\leq C_T \\ \sum_{i=1}^n X_{ij} &= 1 \quad \forall j = 1, 2, \dots, m \\ X_{ij} &\geq 0 \end{aligned} \quad (1)$$

Fig. 2 Descriptive analysis of questionnaire

Table 3 Weights of identified risks based on Friedman's results

No.	Risks	Weight
1	Coordination skills, communication and project leadership	0.0438
2	Lack of sufficient experience in the field of project	0.0451
3	Poor planning and decision making process	0.0605
4	Low quality in technical skill, performance and workmanship	0.0539
5	Low operational productivity	0.0352
6	Technical knowledge and qualifications	0.052
7	Management ability and attitude	0.0438
8	Inadequate training of human resources	0.0438
9	Not taking care of teamwork and lack of morale and motivation	0.0451
10	Responsibility and distribution of risk when needed	0.0605
11	Unavailability of the workforce	0.0452
12	Failure to observe safety precautions	0.0682
13	Flexibility when sudden and unpredictable changes in project	0.0364
14	Incorrect estimates of time, cost and resources	0.0547
15	Human resources protests and interrupting the works	0.0483
16	Ability to estimate predictable conditions and problems	0.0464
17	Similar work experience	0.0414
18	Ability to obtain project approvals and licenses required	0.053
19	Ability to organize and coordinate the risk	0.0309
20	Falling, hurt and injury during the project	0.0418
21	Inability to understand the goals and importance of the project	0.0496

Table 4 Weights of identified criteria for cost based on Friedman's results

No.	Cost criteria	References
1	Management ability	0.131
2	Experience	0.134
3	Project budget	0.181
4	Productivity	0.164
5	Ability to estimate the conditions correctly	0.106
6	Complexity and importance of the project	0.155
7	Knowledge and awareness of the project	0.129

where i and j show candidates and the project's activities respectively. X_{ij} is a decision variable. When $X_{ij} = 1$, i th candidate has been selected for j th activity in the project and on the contrary when $X_{ij} = 0$ i th candidate has not been selected. R_{ij} shows the risk of the i th candidate for allocating in j th activity in the project. $R_{tolerable}$ is defined to present the threshold of organization in dealing with human resources' risks. Based on the criteria identified in the previous step, the main decision-makers in each organization e.g. director manager and etc. determine the level of tolerable risk. The approach for determining the level of tolerable risk is similar to the method used for the evaluation of candidates' risk that will be described in the following section. An important innovation in this study is to minimize risk aversion to the organization from the

company's $R_{tolerable}$ rather than minimizing the risk to the organization. The reason for this is that the minimization of risk will impose costs on the organization and the project as well, while the organization or project itself is able to withstand a certain $R_{tolerable}$. Therefore, it is not necessary to reduce excessive $R_{tolerable}$ of the organization.

Concerning the cost, the cost of i th candidate for j th activity ($C_{ij}I_j$) should be kept as low as possible, taking into account the available budget (C_T). The output of the model was selecting the i th candidate for the j th activity (X_{ij}), indicating the select or not select with values 1 and 0 respectively. The existing objective function has 7 variables as described in Table 5.

In the above model, the values of C_{ij} , R_{ij} and $R_{tolerable}$ are obtained by the user of the model using the additive-veto method described below, and C_T , W_r and W_c values are determined by decision makers of the organization or project. Finally, X_{ij} is obtained by running the model based on the popular solutions of zero-one non-linear programming.

4.2.2 Additive-veto method

The additive-veto is a method used to score the variable, using different criteria associated with that variable. As explained above, there are 21 criteria for risk variables, and 7 for the cost variables, indicating the criteria to score. In the additive-veto approach, a number of decision-making criteria that are more relevant to their

Table 5 Definition of variables

No.	Variables	Description
1	X_{ij}	Decision variable for the selection of i th candidate for j th position
2	C_{ij}	The qualification score for i th candidate to handle j th position
3	l_j	The minimum salary for j th position which is obtained by the opinions of project managers
4	t_j	The duration of j th position which is obtained from scheduling
5	C_T	Available budget to the organization for employing human resources
6	R_{ij}	Risk of i th candidate for j th position in project
7	$R_{tolerable}$	Risk tolerable for organization
8	W_c	Cost priority determined by decision maker from 0 to 1
9	W_r	Priority level of risk determined as $W_r = 1 - W_c$

decision-making process are selected, which act as veto criteria. Dissatisfying the veto criteria leads to an excessive reduction in rating the option under consideration and effectively eliminates the option. Choosing the right criteria as veto criteria depends entirely on decision-makers. Principally, project managers can decide on veto criteria based on the conditions and characteristics of their managed projects. However, it is possible that there is no veto criterion in a project. Specifically, the process of implementing the additive-veto method describes the steps below:

- Among the identified criteria, whose existence in the decision-making process is more effective than others, are selected as the veto criteria.
- Considering the type of variables and problem conditions for the veto criteria, the upper limit (U_j) and the lower limit (L_j) are considered. It should be noted that because the score for each of the criteria in the questionnaire is between numbers 1 through 9, the upper and lower limits must also be specified among these numbers.
- After selecting the upper and lower limits for veto criteria, each option is evaluated against these criteria. The performance of each option is shown in the veto criteria with V_{ij} . This value is determined by the human resources appraisal team, which is scored in numbers 1 through 9 in this study. The following three options for each candidate can be used to determine the veto function (Z_{ij}):

- The performance (V_{ij}) is greater than the upper limit (U_j):

$$Z_{ij} = 1 \quad (2)$$

- The performance (V_{ij}) is less than the lower limit (L_j):

$$Z_{ij} = 0 \quad (3)$$

- The performance (V_{ij}) between upper and lower limits:

$$Z_{ij} = \frac{V_{ij} - L_j}{U_j - L_j} \quad (4)$$

- The final score of each option is shown with R' in the veto criteria.

$$R'_i = \sum_{j=1}^{m'} Z_{ij} \times K_j \quad (5)$$

K_j is the weight of each criterion obtained by the Friedman test.

- The rating of each option in other criteria is also calculated according to the following equation:

$$R''_i = \sum_{j=1}^{m''} v_{ij} K_j \quad (6)$$

where v_{ij} is performance rate is in the context of non-veto criteria.

- The final score of each option in the evaluation process can be calculated according to the following equation.

$$R_i = R'_i \times R''_i \quad (7)$$

In the case of problem with any veto criterion, the value of R'_i would be one.

To calculate the value of $R_{tolerable}$, the steps of veto are applied with the difference that the values of V_{ij} and v_{ij} are the tolerable level of risk for the organization or the project in each criterion. Moreover, to calculate the cost of human resource, each candidate is evaluated based on the veto method as well.

5 Case study

In order to become familiar with how the model is implemented, the various steps described in the previous section are fulfilled in a practical example.

A contractor company in the construction industry needs several workers to build a sports complex. In this

project, the company wants to allocate five positions from among the eligible ones who have provided their resume. The information on assessing candidates for five occupational positions is presented in the following tables, according to the risk and cost criteria. The evaluations were carried out by the appraisal team, including the project manager, head of the workshop and technical assistant (Tables 6, 7).

Table 6 Evaluation of candidates based on risk criteria

Position	P1			P2			P3			P4		P5		
Candidates	A11	A12	A13	A21	A22	A23	A31	A32	A33	A41	A42	A51	A52	A53
r1	3	1	2	5	7	1	6	9	7	9	3	1	6	4
r2	6	5	2	2	3	8	7	1	6	9	4	7	1	2
r3	6	9	1	2	4	6	3	3	1	3	7	2	4	2
r4	2	3	3	3	6	3	2	7	9	4	5	2	2	7
r5	8	8	9	6	2	3	1	4	2	3	3	4	5	9
r6	2	2	3	6	2	3	4	1	5	2	3	6	6	3
r7	6	4	7	1	8	5	1	2	3	9	1	6	7	8
r8	2	6	8	1	2	4	7	9	2	3	7	6	4	8
r9	1	2	3	9	2	3	5	5	5	7	1	2	3	3
r10	1	6	2	7	9	2	1	4	8	9	3	1	5	4
r11	7	9	6	3	7	5	2	1	4	7	9	6	3	3
r12	5	2	5	3	3	3	6	6	9	4	5	8	5	5
r13	3	1	2	3	4	5	5	9	1	9	6	8	1	4
r14	2	5	5	6	9	8	7	1	2	6	5	7	4	4
r15	8	6	3	2	5	8	4	3	6	6	7	5	7	2
r16	2	1	2	1	3	2	4	1	3	2	1	3	4	7
r17	2	3	3	3	4	6	2	8	8	7	4	1	4	6
r18	4	5	2	7	9	8	3	3	3	5	6	2	2	3
r19	1	1	1	2	3	3	3	6	1	2	3	4	2	3
r20	8	6	3	6	6	4	5	7	3	6	8	9	5	6
r21	1	3	3	6	1	5	2	1	7	6	6	5	9	7

Table 7 Evaluation of candidates based on cost criteria

c7	c6	c5	c4	c3	c2	c1	Candidate	Duration (months)	Basic salary (\$)	Position
6	6	4	2	2	7	1	A11	6	1000	P1
7	6	3	2	1	4	6	A12			
6	3	5	7	2	2	4	A13			
3	4	3	8	6	5	2	A21	8	2200	P2
1	5	1	4	5	3	5	A22			
3	2	3	2	2	7	6	A31	12	1300	P3
5	3	6	3	1	2	1	A32			
2	3	6	3	8	6	2	A33			
3	5	2	6	5	6	7	A34			
1	3	3	5	7	4	3	A41	16	850	P4
9	2	3	3	3	3	9	A42			
6	6	4	2	4	4	7	A51	8	3200	P5
7	6	5	7	1	1	6	A52			
8	3	5	7	8	2	4	A53			

Table 8 Level of veto criteria in risk factors

	r1	r2	r3	r4	r5
Upper limit (U_j)	6	5	6	7	5
Lower limit (L_j)	2	2	2	1	3

The third variable is the cost of each candidate. To calculate this variable, firstly human resources should be qualified according to the cost criteria listed in Table 4. Their weights were obtained from the questionnaire analysis and using the Friedman test as depicted in Table 4. The assessment of the candidates' qualified score, the additive-

Table 9 Results of risk evaluation of candidates

	A11	A12	A13	A21	A22	A31	A32	A33	A34	A41	A42	A51	A52	A53
R_i	0.042	0.046	0.014	0.025	0.049	0.044	0.032	0.045	0.045	0.058	0.05	0.027	0.038	0.04

Table 10 Evaluation of the level of tolerable risk and its value

	r1	r2	r3	r4	r5	r6	r7	r8	r9	r10	r11	r12	r13	r14	r15	r16	r17	r18	r19	r20	r21
The level of tolerable risk	3	4	5	8	8	4	5	5	2	2	3	8	3	2	4	5	5	4	4	4	3
$R_{tolerable}$	0.047																				

Table 11 Results of cost evaluation of candidates

	A11	A12	A13	A21	A22	A31	A32	A33	A34	A41	A42	A51	A52	A53
C_{ij}	3.549	3.738	3.786	5.892	2.348	1.729	2.57	5.67	5.723	3.819	4.299	5.936	4.55	9.098
I_j	1000			2200		1300				850		3200		
t_j	6			8		12				16		8		
Total cost of HRM	21,294	22428	22,716	103,699	41,325	26,972	40,092	88,452	89,279	13,600	58,466	151,961	116,480	232,909

As described in the previous steps, there are seven variables in the objective function, except the variable (X_{ij}), the rest of them are determined by the evaluator (user of the model).

The first variable is the risk of each candidate which is calculated by applying the identified risk criteria and additive-veto method. Among 21 risk factors listed in Table 3, their weights were obtained from the questionnaire analysis and using the Friedman test. The risk numbers 1, 2, 3, 4, and 5 are selected as veto criteria by the appraisal team for the project. Tables 8 and 9 show the upper and lower limits for veto criteria and the obtained results of candidates' risk factors, respectively.

The next variable is $R_{tolerable}$. Based on Table 10, the tolerable amount of any risk was detected by the appraisal team according to the organization's requirements and the upper and lower limits were considered for veto risks. As described in the previous steps, the additive-veto method is used to obtain this variable as well with the difference that the values of V_{ij} and v_{ij} are the tolerable level of risk for the organization in each criterion.

Table 12 Weight of risk and cost objective

	W_r	W_c
Weight	0.3	0.7

veto method was applied. The cost criteria numbers 3 and 7 were considered as veto criteria with upper and lower limits of 8 and 2 for the criterion No. 3 and 5 and 1 for criterion No. 7 respectively. By applying the steps of the additive-veto method the qualification score could be calculated for each candidate with the consideration that the values of V_{ij} and v_{ij} are the performance of candidates in the cost criteria. The results of the evaluation of candidates are shown in Table 11. Moreover, the total cost (C_T) for employing human resources is about \$270,000.

Before solving the model, it is necessary to prioritize the weight of risk and cost objective by the appraisal team. Therefore, at this stage, W_r (risk priority for the decision-maker) and W_c (cost priority for the decision-maker) are determined in this example, as in Table 12:

The objective function of the present problem was solved by the implementation of the Lingo software, with choices according to Table 13.

The results demonstrated in Table 13 present an optimized human resource selection for five job positions in the project. Since the proposed model is based on some identified criteria and the results are dependent on several variables including the characteristics of candidates, the appraisal team's opinions and the budget for hiring human resources, decision-makers need to be careful and conservative. By changing the value of each of them, the final results will be altered. It seems that among these variables, the results are very sensitive to the appraisal team's opinions and they are very effective in the final answer since the risk of candidates, the tolerable level of risk and the qualifying scores for calculating the cost of candidates are directly related to their opinions. Therefore, decision-makers should be aware of the limitations of the model and the arrangement of this team should be done concisely.

In other words, since the proposed model has some limitations such as dependency to the opinions of respondents, differences among the construction industry of various countries and etc. the model should be considered as a decision support system and its results should be reviewed and discussed by decision-makers before finalizing.

6 Conclusion

Today human resources are considered as one of the competitive tools of organizations that can impact the success of a project. The HRM category in the construction industry is particularly important due to the nature of the projects' temporality and the intrinsic complexity of the projects and is generally facing serious challenges. Choosing the right human resources for projects is one of the most important steps of HRM because improper selection can lead to the HRM problem until the end. Choosing decent people or, actually lower-risk people, are naturally high-cost because the increased level of experience and expertise reduced the risk of employed people, but people with the necessary knowledge and expertise essentially require a lot of money. In general, the purpose of the present research is to select appropriate people based on project conditions, focusing on optimizing risk and cost in human resource selection. In other words, this article has sought to optimize the

risk-cost criteria of people employed. In order to achieve the desired goal, after collecting the risk-cost criteria of human resources from credible sources and their summarization, a questionnaire was first distributed to determine the importance of each of these criteria. The significance of each criterion (in the area of risk-cost) was identified by skilled and experienced people and ultimately each one was given a score. In order to measure the cost, the qualifications of each candidate were measured on the basis of seven criteria and the score values earned were multiplied by the base salary determined by the organization. Then, the additive-veto method, as an MCDM method, was used to determine the risk-cost level of each of the candidates for a specific position in the project. Finally, in order to reach the goal of the research, a model was developed along with the zero-one non-linear programming approach. In the area of risk measurement, the $R_{tolerable}$ concept of the organization was introduced, and in the optimization model, the risk imposed by the selected individuals had the least deviations from the organization's $R_{tolerable}$; and unlike other studies, the focus was not on risk reduction since the concept of risk reduction usually will increase the cost of a project. Eventually, by implementing the proposed model in a case study, out of fourteen individuals for the management of five organizational positions, a group of individuals was set to optimize their risk level in accordance with the organization's $R_{tolerable}$ and cost criteria considering the budget provided by decision-makers for the employment of individuals.

Although the proposed model is capable enough to adapt to the opinions of experts and has enough novelty in terms of applying the concept of the tolerable risk, it has some limitations. The results of the proposed model are dependent on the output of questionnaires. The model applies the questionnaire to make it match with different conditions in different situations but the challenging point is its dependency on the opinions of experts. The criteria used for risk and cost evaluation of candidates, the weights of criteria and the given score to candidates are highly dependent on the experts' opinions. Therefore, decision-makers should pay attention to use this model as a decision support system and the results of the proposed model should be validated.

Since the authors are familiar with the different aspects of this work, future researches are suggested to optimize the cost-risk of human resource selection in the organization instead of a project. Moreover, the proposed model optimizes the selection of human resources while other research can be defined to optimize the allocation of an appropriate task for an individual who is multiskilled. To develop this idea, the concept of this paper can be applied with proper modifications.

Table 13 Weight of risk and cost objective

	Position				
	P1	P2	P3	P4	P5
Selected candidate	A_{12}	A_{22}	A_{31}	A_{41}	A_{52}

Acknowledgements Not applicable.

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

Consent for publication Not applicable.

Ethical approval Research involving human participants and the authors declare the informed consent by all participants. Moreover, no personal information of participants has not been published in the paper. All procedures were followed in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national).

Informed consent Informed consent was obtained from all participants for being included in the study.

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