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APPLICATION OF FUZZY CBR AND MODM APPROACHES IN THE PROJECT PORTFOLIO SELECTION IN CONSTRUCTION COMPANIES*

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Abstract– Project selection is a fundamental decision in construction companies. Regarding the high complexity and dynamic nature of construction projects, the level of uncertainty in this industry is very high. Portfolio selection strategy can be considered as one of the best ways for mitigating the risk of project selection. With respect to the considerable importance of project portfolio selection in reducing the risk to a company, developing research in this area is crucial. The main focus of this paper is to present a hybrid model according to the fuzzy case-based reasoning for prescreening of projects according to the factors generating risk in the construction industry and the historical records of the company, also allocating the most appropriate prescreened projects to the portfolio of company with the use of zero-one linear goal programming. A real case study has been presented for model implementation and for more understanding.

Keywords– Risk, project selection, portfolio, Fuzzy case-based reasoning, linear goal programming

1. INTRODUCTION

Project selection is an important and repetitive activity in the construction industry. Project selection in deciding whether to bid for a job or not is a vital and recurring strategic decision in construction firms as many contractors obtain a large portion of their projects through competitive bidding [1]. The original project selection is related to choosing a portfolio of projects that meets an organization's objectives without exceeding available capital resources [2]. Project portfolio selection can be considered from various viewpoints, including employer, contractor and consultant. Each part has its special concerns but for contractors, project portfolio selection is a crucial phase. From another point of view, the construction industry is subject to more risk and uncertainty than other industries [3]. Some researchers have argued that contractors are poor in responding to the risk and are not capable of handling risks [4,5]. Limited resources of contractor firms, strategy implementation, the complex nature of the construction industry, and the dynamic and unique features of project portfolio selection are some reasons for developing research in project portfolio selection in the construction firms. Mullich showed that managing risks and obtaining high benefit in construction projects is probable by using a portfolio theory [6]. Proper decision-making in a risky circumstance, especially in the construction industry, can achieve a considerable benefit for its participants. Certainly, each firm has a good or bad experience in the project selection phase with regard to their risks during its life. Computers can review a huge amount of historical data in order to identify similar cases and provide useful information. Precious knowledge and experience hidden in the data can be reviewed/recalled and developed systems can provide appropriate suggestions [7]. Therefore providing a systematic approach for using the information of previous projects with respect to their risks

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and their results in the portfolio of a company would be useful for making appropriate decisions. A case-based reasoning (CBR) approach, which is a method for solving problems by making use of previous similar cases, can provide such a tool. Therefore, this study focuses on the CBR method and demonstrates how the model uses CBR method for the evaluation of the risk of projects. Fuzzy set theory will help CBR methods in working with linguistic variables, which are the most important and applicable variables in the evaluation of alternatives, especially in the construction industry. Moreover, this paper needs the help of zero-one linear goal programming (ZOLGP) for employing the outputs obtained from the fuzzy CBR model to select the best optimized portfolio. The structure of the current paper is planned to describe the essence of the work and to clarify the methodology and main interest areas in the introduction section. A brief literature review has been presented in the literature survey. The next section reviews the concept of CBR. The developed systematic model is provided in section 4, and in section 5 the model has been applied in an illustrative example to demonstrate the model application and, finally, in the conclusion section a brief result of the paper will be presented.

2. LITERATURE REVIEW

There are several researches in the construction project selection considering risk. Moselhi and Deb presented a simple methodology for the selection of projects based on risk. Their method applied multi-objective decision criteria (MCDM) and took into account the uncertainties associated with each individual objective [8]. Tah et al. developed a model for evaluating contractors' risks in the tendering phase. They used the principles of fuzzy set theory for covering the construction risks [9]**.** Han et al. proposed a methodology for international project selection based on the risk factors [10]. Ziara et al. developed a risk-based analytical hierarchy process for infrastructure project prioritization [11]. The inherent uncertainties of the construction industry led Liu and Ling to propose a combined framework with the use of fuzzy logic and neural network for bidding price [12]. According to the literature survey, models developed for project selection can be categorized into two main groups inclusive of stochastic approaches and fuzzy approaches. Stochastic approaches are the most important tools when financial risks are important, but investigations have changed their contributions to fuzzy approaches recently. [13-15]
Vergara applied portfolio theory for the first time in the construction industry. In the first step of his model he analyzed proposed projects one by one. After this, he evaluated the status of the existing portfolio of organization and finally the appropriate projects were selected for satisfying the organization's objective, which is the improvement of the characteristics of the present portfolio of organization [16]. In 1981, Kangari and Boyer presented a model based on the portfolio concept in the project selection, but in 1988 Kangari and Riggs confessed that the model had some serious problems and they said that the calculation of the covariance of projects is not as simple as in marketing [17,18]. Han et al. used the portfolio theory with financial analysis for selection and evaluation of international projects [19]. Veshosky spoke about the portfolio approach and the diversification strategy for improving the position of firms in the market and for starting new business. His investigation showed the portfolio theory could satisfy his mentioned objects in American firms [20]. Olsson compared the single project management and project portfolio management in his study. He proposed a methodology based on the portfolio theory for managing risk in a multi-project environment [21]. Ravanshadnia et al. investigated the effects of portfolio criteria on the decision-making. They showed that the results of project selection with and without regard to the synergy of projects and portfolio considerations are completely different [22]. While project selection process should be done taking the existing project portfolio into consideration, the number of investigations conducted in this area is not enough. Models developed in the construction for project selection focus on the evaluation of project and do not consider the effect of selection on other fields such as resource

allocation. Furthermore, some existed models for project portfolio selection usually have some limitations which lead to reducing their applicability and user-friendliness. This paper intends to present a simple and applicable model in the evaluation of candidate projects for adding to the existing portfolio.

3. CONCEPT OF CBR

Primary works in developing CBR concepts were done by Roger Schank at Yale University in the early 1980s. Watson formally proposed CBR and used it in the enterprise systems [23]. Different researchers have developed CBR concept and applied it in various subjects such as design [24], deterioration predictions [25], recognition problems [26], vendor selection [27]. CBR is based on the idea of making use of solutions to previous problems for solving new ones. It is conceived as a technique similar to the aspect of human reasoning in which experiences for guidance in solving current problems are referred [27]. Aamodt and Plaza have described the CBR as a cyclical process, comprising the “4R process” [28]:

1. Retrieving the most similar case(s) from the case library when a new problem is encountered
2. Reusing the most similar cases for solving the new problem
3. Revising step for better adaptation of the suggested solution to the condition of problem
4. Retaining the new solution as a new case for promoting the capability of knowledge base

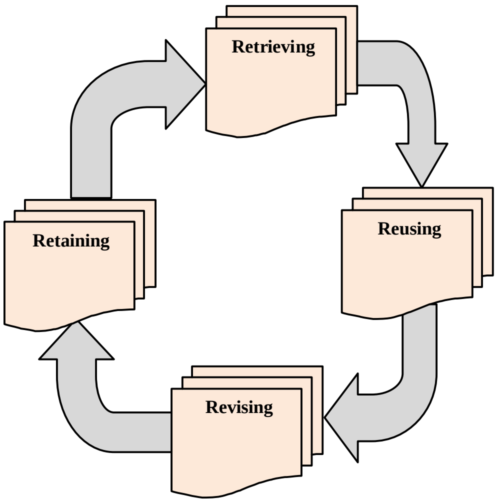

Fig. 1. Cyclic process of CBR

4. HYBRID MODEL FOR PROJECT PORTFOLIO SELECTION

The proposed model constitutes three main steps and several sub-steps in each category. Through the first step, this paper establishes a fuzzy CBR model to prescreen proposed alternatives (projects) with respect to their risk. In the second step, the desired risk level of company (DRLC) is calculated. This parameter determines what level of risk the company can tolerate according to cases (projects) which are in the knowledge base of CBR system. Finally, ZOLGP is used to optimize new project portfolio with the outputs obtained from two previous steps. The proposed model for project portfolio selection with the use of fuzzy CBR and ZOLGP comprises the steps shown below:

Step1: Prescreening phase: The initial evaluation and ranking of proposed projects are the two main concerns of this phase. A fuzzy CBR model measures the similarity between new projects and old cases with respect to the risk factors. This step includes the following sub-steps.

Step 1.1: Developing linguistic variables**:** The concept of a linguistic variable is very useful to describe a situation that is too complex or has vagueness. Term values are approximated by their membership functions by using fuzzy logic arithmetic [29]. There are several fuzzy numbers but in the construction industry, triangular and trapezoidal fuzzy numbers are the most used [30]. In this paper, trapezoidal and triangular fuzzy numbers are used. Table 1 presents the linguistic terms and their membership functions.

Table 1. Linguistic terms and fuzzy numbers

Linguistic terms	Fuzzy numbers
Very High (VH)	(0.8 , 0.9 , 1, 1)
High (H)	(0.7 , 0.8 , 0.9)
Fairly High (FH)	(0.5, 0.6, 0.7, 0.8)
Medium (M)	(0.4, 0.5, 0.6)
Fairly Low (FL)	(0.2, 0.3, 0.4, 0.5)
Low (L)	(0.1, 0.2, 0.3)
Very Low (VL)	(0 , 0 , 0.1, 0.2)

Step 1.2: Set up risk factors**:** There exist several risks in the construction industry, but working with all of them is not possible and applicable. In each country, there exist different parameters which lead to generating risk in construction projects and they depend directly on the condition of the countries or projects. In this section, each company should prepare a set of risk factors derived from academic researches, experts' experience and previous historical records. Weighting is the next step for determining the importance of risks. One of the simple methods suggested by authors is that experts express their opinions about the probability and consequence of each risk by a number between 1 and 9 (1 is the lowest limit). Finally, there would exist a number from a multiplication between the probability and consequence of each risk based on each expert judgment. For the next step, a mean of their judgments for each risk is calculated. In order to have a final normalized weight, a normalization process will be done based on the following equation:

$$w_i = \frac{x_i}{\sum_{i=1}^{n} x_i} \quad (1)$$

Where x_i is the mean weight of the i^{th} risk based on a mean of expert judgments and w_i is a normalized weight of the i^{th} risk that would be between 0 and 1.

Step 1.3: Development of case-base**:** Some previous projects which had positive impacts on the progress of company can be placed in the knowledge base of the system. For a company with different projects in various fields, decision makers should define different parts with respect to the nature of the projects. For example, decision makers should classify road projects, structural projects, piping etc. in separate sections in the knowledge base and the step 1.2 should be done for each type.

Step 1.4: Retrieve the most similar case**:** Fuzzy CBR applies two criteria including risk and type of projects for choosing alternatives (projects) with the most similarity to experience of company. Retrieving the most similar solution is done by various methods but the most common technique is to determine the similarity of the present problem and stored cases. In this study, the similarity between a target case and a source case was calculated by weighted summation approach developed by Kolodner [30],

$$S_{NO} = \frac{\sum_{i=1}^{n} w_i \times sim(f_i^N, f_i^O)}{\sum_{i=1}^{n} w_i} \quad (2)$$

S_{NO} represents the similarity between new problem (N) and old cases (O) where the value 1 represents the exact similarity between them. w_i is the weight of i^{th} attribute and $sim(f_i^N, f_i^O)$ determines the similarity of new problem and stored case according to the i^{th} attribute. In this paper, fuzzy CBR is considered and parameters are inserted to the model as linguistic variables. Various similarity measures have been proposed to calculate the degree of similarity among fuzzy numbers but in this paper the radius of gyration developed by Deng et al. [31] is used. If the general fuzzy number is demonstrated as $A=(a_1,a_2,a_3,a_4,w)$ where,

$$A=\begin{cases} 0 & \\ \dfrac{x-a_1}{a_2-a_1} & x\le a_1 \\ & a_1\le x\le a_2 \\ w & a_2\le x\le a_3 \\ \dfrac{a_4-x}{a_4-a_3} & x\ge a_3 \end{cases} \tag{3}$$

then the similarity between A and B is calculated as shown below:

$$Sim(A,B)=1-\frac{\sum_{i=1}^{4}|a_i-b_i|}{4}(1-|r_x^A-r_x^B|)^{B(S_A,S_B)}\frac{\min(r_x^A,r_x^B)}{\max(r_x^A,r_x^B)} \tag{4}$$

Where,

$$r_x^A=\sqrt{\frac{(I_x)_1+(I_x)_2+(I_x)_3}{((a_3-a_2)+(a_4-a_1))\frac{w_A}{2}}}\ and\qquad r_y^A=\sqrt{\frac{(I_y)_1+(I_y)_2+(I_y)_3}{((a_3-a_2)+(a_4-a_1))\frac{w_A}{2}}} \tag{5}$$

$$(I_x)_1=\frac{(a_2-a_1)w_A^3}{12},\quad (I_x)_2=\frac{(a_3-a_2)w_A^3}{12}\quad (I_x)_3=\frac{(a_4-a_3)w_A^3}{12} \tag{6}$$

$$(I_y)_1=\frac{(a_2-a_1)^3w_A}{4}+\frac{(a_2-a_1)a_1^2w_A}{2}+\frac{2(a_2-a_1)^2a_1w_A}{3}$$

$$(I_y)_2=\frac{(a_3-a_2)^3w_A}{3}+\frac{(a_3-a_2)a_2^2w_A}{1}+\frac{(a_3-a_2)^2a_2w_A}{1}$$

$$(I_y)_3=\frac{(a_4-a_3)^3w_A}{12}+\frac{(a_4-a_3)a_3^2w_A}{2}+\frac{2(a_4-a_3)^2a_1w_A}{3} \tag{7}$$

$$S(A,B)=\begin{cases}1 & if\quad S_A+S_B>0\\ 0 & if\quad S_A+S_B=0\end{cases}$$

$$S_A=a_4-a_1\qquad\qquad S_B=b_4-b_1 \tag{8}$$

Output of this step is a list of ranked projects considering risk.

***Step 1.5: Revise the ranking of projects*:** CBR model can demonstrate an overall view about the proposed alternatives. Through this phase, a list of prioritized projects is reconsidered based on the present situation where the decision is made. Authors propose all of the decision makers can hold a session and review or customize the prioritized list with the use of some tools such as brainstorming or negotiation.

Step 2: Determining the (DRLC): It seems that the best way for determining the DRLC is to refer to knowledge base or stored cases of CBR model. Old cases are the good experience of a company's background and reveal whether the company can handle projects with these characteristics. Projects stored in knowledge base are evaluated based on risk and their average score represent the DRLC. There are several methods for determining the DRLC but fuzzy MCDM solutions are more useful than the others. The simple additive weighting (SAW) method is probably the best known and most widely used multiple attribute decision-making (MADM) method [32]. SAW can be transferred into fuzzy SAW by inserting the expert's judgments and working with linguistic terms. In this approach, each project can obtain a score as in equation (9):

$$U = \sum_{i=1}^{n} w_i r_{ij} \tag{9}$$

where w_i is the weight of criterion i^{th} and r_{ij} is the rate of alternative j^{th} with respect to criterion i^{th}. U demonstrates the level of risk that a company could handle in the previous experience so the average score obtained by each case presents the DRLC (For more information about fuzzy calculation of equation (9) refer to [32]). The transformation of the DRLC to the crisp number is essential for calculating in other steps. Defuzzification operator is a suitable tool for this purpose. Because most previous researchers have applied the centroid index (CI), the CI is also used in this paper. The centroid of a fuzzy number is representative of its characteristics. The CI of x value with the area of $A(x)$ can be expressed as:

$$CI = \frac{\sum_{x_{\min}}^{x_{\max}} xA(x)}{\sum_{x_{\min}}^{x_{\max}} A(x)} \tag{10}$$

Step 3: Development of ZOLGP: Several useful tools exist for solving portfolio problems, but multi objective decision-making (MODM) approaches are more capable than others in satisfying problems with various goals, therefore, linear goal programming is used in this paper. Because of the nature of selection problems, the authors decided to use zero-one linear goal programming. ZOLGP optimizes alternatives with respect to some various goals and constraints.

Some general variables used in ZOLGP: In the formulas below there are some common variables which include: X_i: Decision variables, $X_{ij} = 1$ if project i is in the portfolio and start in period j, else $X_{ij} = 0$, N : Total number of projects being proposed, T: Various periods in the strategic planning, d_1^-: Negative deviation, d_1^+ : Positive deviation,

In this paper, goals are defined as follows:

1. Minimizing the difference between the risk of project portfolio and DRLC: If the risk of each project in the j^{th} period is presented by r_i, this goal would be defined as Eq. (11):

$$\sum_{i=1}^{N} \sum_{j=1}^{T} r_i X_{ij} + d_1^- - d_1^+ = RELC \tag{11}$$

2. Maximizing the benefit of project portfolio: If the benefit of the i^{th} project presented by b_i and the expected benefit of the portfolio is shown with B, this goal can be defined as Eq. (12):

$$\sum_{i=1}^{N} \sum_{j=1}^{T} b_i X_{ij} + d_2^- - d_2^+ = B \tag{12}$$

3. Qualitative goals: If a company has some qualitative goals such as Q, this goal can be defined as equation (13). In this equation q_i is the weight of the i^{th} project in the evaluation process with regard to the goal.

$$\sum_{i=1}^{N} \sum_{j=1}^{T} q_i X_{ij} + d_3^- - d_3^+ = Q \tag{13}$$

Moreover, constraints would be defined as follows:

1. Resource constraints: A company can model its limitations in supplying various resources such as financial, human, and equipment. If the project planning is divided into T periods and the total resource in period k is presented by AF_k and the needed resource for the i^{th} project is presented by $C_{(i,k+1-j)}$, this constraint can be formulated as equation (14):

$$\sum_{i=1}^{N} C_{(i,k+1-j)} x_{ij} \le AF_k \quad For \quad k=1,\dots,T \tag{14}$$

2. Start of each project once at the same time: This constraint guarantees that each project can start at once. Equation (15) presents this limitation.

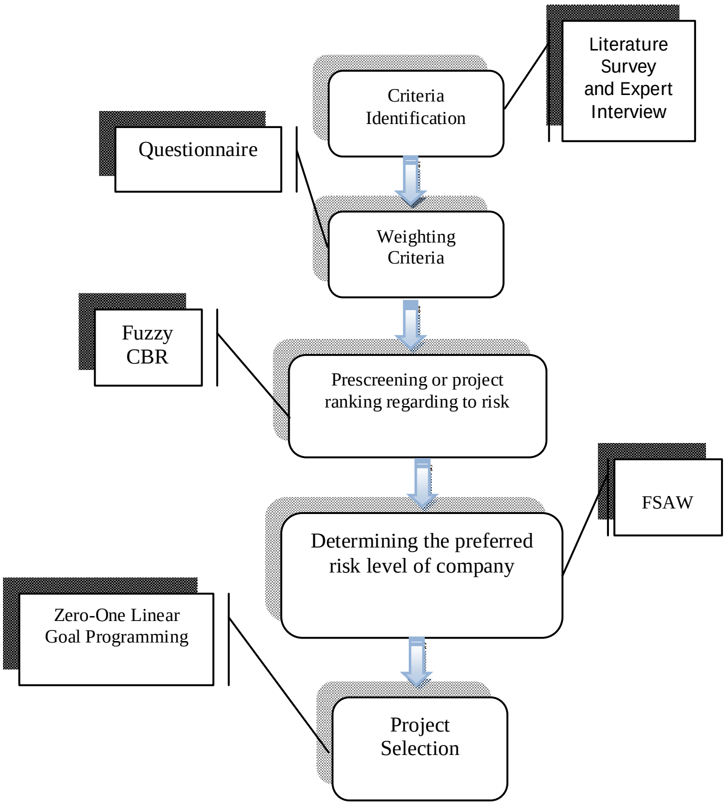

Fig. 2. The proposed model chart

$$\sum_{j=1}^{T} (x_{i(j+1)} \ge x_{ij}) \quad for \quad i=1,\dots,N \tag{15}$$

3. The completion of projects: Equation (16) shows that the i^{th} project, whose duration is expressed by D_i should be finished in the project portfolio planning.

$$\sum_{j=1}^{T} j x_{ij} + D_i \le T+1 \quad for i=1,\dots,N \tag{16}$$

If a company needs to satisfy other goals and constraints, they can also be added. In general, Fig. 2 depicts the steps of the proposed model.

5. MODEL IMPLEMENTATION IN A REAL CASE

For better understanding, the authors have prepared an example in a real situation. In this section, a set of proposed projects is offered and a project or projects should be selected, which are suitable for their present project portfolio. The main field of this company is road and dam construction but it has some useful experience in other fields. The results of the implementation of the proposed model in this company are as follows:

Step 1. Prescreening phase:

Step1.1. Decision makers develop their desired linguistic terms and related fuzzy numbers. Table (1) represents the linguistic terms and their related fuzzy numbers.

Step1.2. Risk identification is the main concern of this step. Authors used an unofficial investigation conducted in a university. This research surveyed contractor companies in Iran. Risks, their categorization and weights were expressed as shown in Table (2). Weights presented in the Table (2) were calculated with the use of AHP approach in that mentioned investigation.

Table 2.Categorization and risk

No	Risk Criteria					
	a) Financial and economical risk (0.112)	b)Industry (0.184)	c)Contract (0.261)	d)Company (0.145)	e) Resource (0.168)	f)Project risk (0.133)
1	a-1) Interest rate (.018)	b-1)Variation in government policies (0.043)	c-1) Type of contract (0.044)	d-1)Improper strategy in selection of region for work (0.022)	e-1)Lack of expert human resource (0.047)	f-1)Design complexity (0.036)
2	a-2) Inflation rate (0.036)	b-2)Variation in production rate of principal materials (0.044)	c-2)Type of payment (0.042)	d-2)Improper strategy in doing special type of projects (0.023)	e-2) Lack of professional sub-contractors (0.039)	f-2)Execution complexity (0.039)
3	a-3)variation of petroleum price (0.025)	b-3)International limitation (0.0326)	c-3)Low credibility of employer (0.047)	d-3) Lack of enough experience of project management team (0.03)	e-3) Shortage of equipment and machines (0.039)	f-3)Geographical and weather condition of project (0.022)
4	a-4)Dependency to special moneylenders (0.029)	b-4)Variation in tariff (0.025)	c-4) Low financial ability of employer (0.054)	d-4)Weak contractor relationship with employer organizations (0.031)	e-4)Difficulty in supplying materials (0.041)	f-4)Force majors (0.013)
5		b-5) Permission license (0.022)	c-5) Unfamiliarity of consultant to technical work (0.026)	d-5)Lack of expert managers (0.039)		f-5)Unpredictable changes (0.023)
6		b-6)Environmental rules (0.017)	c-6) Lack of cooperation history with consultant (0.013)			
7			c-7)Ambiguity in contract documentation (0.035)			

Step1.3. Suppose there are 4 projects in the knowledge base of a company. Table (3) presents old projects (Case NO) and proposed projects (NP NO) and their risk evaluations regarding the main criteria or key risk factors according to experts' judgment.

Step 1.4. Table (4) demonstrates the results of implementing the similarity measurement with the use of radius of gyration developed by Deng et al.

Table 3. Risk evaluation of old cases and proposed projects

No	Risk criteria					
	Financial and Economical Risk	Industry	Contract	Company	Resource	Project risk
Case NO.1	FL	H	M	M	FL	H
Case NO. 2	M	H	H	M	M	M
Case NO.3	M	M	FH	FL	L	M
Case NO.4	FH	L	M	L	M	FH
NP NO.1	FH	M	H	M	M	FL
NP NO. 2	M	H	H	M	M	M
NP NO.3	H	M	VH	FL	H	L
NP NO.4	VH	M	VH	M	VH	VH

Table 4. Ranking of proposed projects with the use of fuzzy CBR

Project	Similarity	Rank
NP NO.1	0.9019	2
NP NO.2	0.9231	1
NP NO.3	0.8559	3
NP NO.4	0.8429	4

Step 2:_ This section uses fuzzy SAW for extracting the DRLC. ZOLGP will use the DRLC as one of its parameters for optimizing the portfolio of company in the next step. With implementation of fuzzy SAW, old cases, which have been evaluated in the previous steps (Table (3)), are used for determining the fuzzy number of DRLC (Fig. 3). Difuzzification tool is used and the CI of the final fuzzy number of DRLC is 0.4346 from 1.

Step 3: The final step in the model implementation is to apply ZOLGP for optimizing the new portfolio based on results acquired from prescreening phase and step 2. According to the decision makers' strategy, two projects which obtain top scores in the prescreening phase are candidates for constituting new company portfolio. At present, the company has a portfolio comprised of three projects. Table (5) shows the specifications of the existing portfolio. With respect to the existing project's planning and the assumed planning of the proposed projects, the expected cost and benefit table (Table 6) can be calculated. In this table, project number 1 to 3 are the existing projects and the others are proposed projects. LINDO software version 6.1 was applied. The problem was solved in a few minutes and the final answer is shown in Fig. (4). According to the decision makers' opinions, weights of all goals are equal.

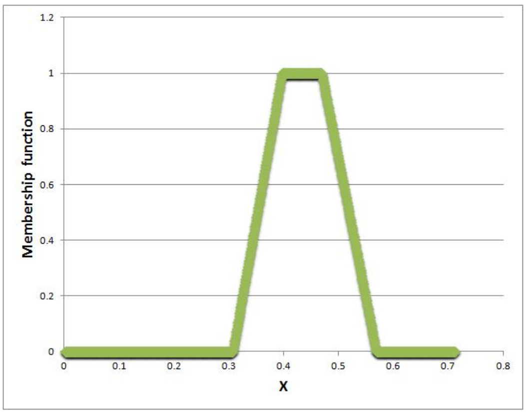

Fig. 3.The final fuzzy number of DRLC

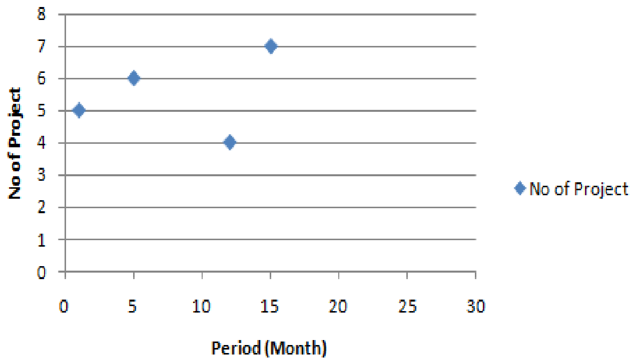

Fig. 4. Scheduling of Portfolio

Table 5. Evaluation of existing project

No	Description	The evaluated risk number	Expected benefit (in million dollars)	Type of contract	Duration (month)	Physical progress	Programatic progress	Financial progress	Financial weights	The existing portfolio risk number
1	Asaluyeh-Parsian highway construction	0.37105	10.4	EPC	34	80%	91%	77%	54.7%	0.4063
2	Homa infrastructure construction	0.36078	1.8	DBB	12	18%	22%	11%	9.50%	
3	Ardabil rail way construction	0.47236	5.1	EPC	36	34%	52%	13%	35.80%	

Table 6. Execution cost and expected benefit distribution of projects

	Month	Proj. No.1		Proj. No.2		Proj. No.3		Proj. No.4		Proj. No.5	
		EB **	EC*	EB	EC	EB	EC	EB	EC	EB	EC
1	1	6968.7	51843.4	1041.1	5205.5	416.4	2776.3	275.8	1532.1	461.3	2096.7
	2	4759.9	42799.5	2023.4	10116.8	1296.0	8640.2	1341.4	7452.3	2243.7	10198.5
	3	2040.5	40202.6	2266.9	11334.3	1708.3	11388.4	1768.1	9822.7	2957.3	13442.3
	4	1795.6	25277.9	1987.1	9935.6	2075.7	13837.9	2148.4	11935.4	3593.4	16333.5
	5	1576.5	6282.7	2055.8	10279.0	1740.9	11605.7	1801.8	10010.1	3013.7	13698.8
	6	13180.8	-	2070.5	10352.4	1785.9	11905.7	1848.4	10268.8	3091.6	14052.9
2	7	-	-	1709.3	8546.4	1729.3	11528.8	1727.8	9598.8	2889.9	13135.9
	8	-	-	1605.6	8027.9	1716.9	11445.9	1777.0	9872.2	2972.2	13510.2
	9	-	-	1009.5	5047.6	1895.5	12636.7	1651.4	9174.3	2762.1	12555.1
	10	-	-	250.9	1254.6	2189.2	14594.4	1085.9	6032.8	1816.3	8255.9
	11	-	-	-	-	2339.1	15594.3	2110.5	11725.3	3530.1	16046.0
	12	-	-	-	-	2584.5	17230.1	2364.5	13136.2	3954.3	17974.2
3	13	-	-	-	-	2962.6	19750.6	2072.7	11515.1	33286.0	151300.0
	14	-	-	-	-	2671.7	17811.6	2144.3	11912.7	-	-
	15	-	-	-	-	2536.6	16910.7	2159.7	11998.2	-	-
	16	-	-	-	-	2172.6	14483.7	1782.9	9904.9	-	-
	17	-	-	-	-	2068.0	13786.6	1674.7	9303.6	-	-
	18	-	-	-	-	1947.4	12982.8	1053.1	5850.3	-	-
4	19	-	-	-	-	1784.5	11897.0	261.8	1454.2	-	-
	20	-	-	-	-	1649.8	10998.9	-	-	-	-
	21	-	-	-	-	1576.9	10512.6	-	-	-	-
	22	-	-	-	-	1499.8	9998.7	-	-	-	-
	23	-	-	-	-	1183.7	7891.2	-	-	-	-
	24	-	-	-	-	838.7	5591.2		-		-

*EC: Expected Cost (Hundred Dollars)

**EB: Expected Benefit (Hundred Dollars)

With regard to the concept of bid/no-bid and selection problems, choosing projects and starting them in future periods is impossible, so the earliest selection (first period) based on the obtained schedule is the best solution of problem. In this example, project No 5 is the best choice. Regarding the concept of model developed by this paper, project No 5 is a suitable choice when decision makers want to optimize the portfolio of company by selection of new projects with respect to the level of risk that the company can endure.

6. VALIDATION

Validation is a demonstration that a model within its domain of applicability possesses a satisfactory range of accuracy consistent with the intended application of the model [33]. However, standard policies and procedures do not currently exist for determining which techniques are appropriate for use to validate a specific model [34]. For investigating the applicability, comprehensiveness, and user-friendliness of the model, Ravanshadnia et al. [35] developed a structured questionnaire. In this paper, the authors developed a face-to-face interview with decision makers who offer their idea about the case for evaluating the proposed model. This interview consists of four main questions:

1. Comprehensiveness: Does the proposed method cover the required project portfolio selection considerations?
2. Applicability: Is the proposed method applicable for project portfolio selection in construction companies?
3. User-friendliness: Is it easy to use the proposed method?
4. Practitioner's support: Do you support the implementation of the proposed framework by this paper in your company for project portfolio selection?

Authors implemented the face-to-face interview to decision makers. The duration of each session was about an hour. Authors asked decision makers to answer some questions in each area. For instance, in "Comprehensiveness" area, authors asked some questions such as "Does the selected project portfolio satisfy your expected benefit?", "Based on your experience, does the selected project portfolio optimize resource allocation?" and " Based on the nature of projects and your experience, do the projects existing in the selected portfolio harmonize with the strategy of the company?" and etc. Regarding their answers, each criterion can be approved or not. Table 10 shows the results of analyzing responses.

Table 7. Results of questionnaire responses

Criteria	Positive Answer	Neutral Answer	Negative Answer
Comprehensiveness	71%	0%	29%
Applicability	58%	12%	30%
User-friendliness	51%	0%	49%
Practitioner's support	65.3%	0%	34.7%

Results revealed in the table above assured authors about the comprehensiveness, applicability and customer's support of the proposed framework by this paper. Based on the above table, respondents express that they are somewhat uncomfortable with the user-friendliness aspect of the proposed framework, so authors suggest developing software for mitigating the decision makers' concerns about various calculations of model and they hope to implement this idea in the future works.

7. CONCLUSION

This paper offers a new framework in bid/no-bid strategy by implementing the new project portfolio selection methodology based on the risk. The Optimization of the portfolio of company by adding new projects is the main concept of this paper. Solving problems by making use of previous similar cases is an applicable idea, so authors applied the fuzzy CBR method for prescreening of the proposed projects.

Paying attention to the complexity and dynamic nature of the construction industry is necessary, also poor performance with increasing cost and time delays is the result of inattention to the numerous factors generating risk in the construction projects. Therefore, it is necessary to consider factors generating risk in the prescreening phase. In the risk management process attention to the abilities of partners, who are responsible for handling risk is very important. The DRLC identifies the level of risk, which company can endure and handle it. Authors determine the DRLC by evaluating risk of projects in the knowledge base (old cases) with use of fuzzy SAW. Finally, zero-one linear goal programming is used for getting the optimized point in risk and income interaction (portfolio theory) based on the present status of the company and previous successful experience. This model is user friendly because of its capability of working with expert's linguistic terms and using a fuzzy set theory. This model is also very flexible for being implemented in all companies because of its adjustment to the present condition. It seems the concept explained in this paper can be useful for the selection of the best strategy in bid/no-bid decision-making. As the authors discussed the restraints and their assumption, further research can be developed for eliminating expressed assumptions. Other researchers can propose a model considering interdependencies among projects for optimization of portfolio. The second task can be defined in the other fields, not considering the risk factor or by combining various objects for the selection of the best project. Finally developing software is a good idea for satisfying users' convenience.

REFERENCES

1. Oo, B. L., Drew, D. S. & Lo, H. P. (2008). Heterogeneous approach to modeling contractors' decision-to-bid strategies. *J. Const. Eng. & Manage.*, Vol. 134, No. 10, p. 766.
2. Huang, X. (2007). Optimal project selection with random fuzzy parameters. *Int. J. Production Economics*, Vol. 106, pp. 513-522.
3. Flanagan, R. & Norman, G. (1993). *Risk management and construction*. Black-well Science.
4. Ahmed, S. M., Azhar, S. & Ahmad,I. (2002). Evaluation of Florida General Contractor's risk management practices. *Journal of Construction Engineering*, CIB, Vol. 17, No. 1, pp. 4-11.
5. Baloi, D. & Price, A. D. F. (2003). Modeling global risk factors affecting construction cost performance. *International Journal of Project Management*. Vol. 21, No. 4, pp. 261-269.
6. Mullich, J. (2008). Project portfolio management for the new millennium. Information Week http//www.primavera.com.
7. AbouRizk, S. M. & Dozzi, S. P. (1993). Application of computer simulation in resolving construction disputes. *J. Const. Eng. & Manage.*, Vol. 119, No. 2, pp. 355–373.
8. Moselhi, O. & Deb, B. (1993). Project selection considering risk. Construction Management and Economics, Vol. 11, pp. 45-52.
9. Tah, J. H. M., Thorpe, A. & McCaffer, R. (1993). Contractor project risks contingency allocating using linguistic approximation. *J. of Computing Systems in Engineering*. pp. 281-293.
10. Han, S., Diekmann, H., James, E., Lee, Y. & Ock, J. (2005). Contractor's risk attitudes in the selection of international construction projects. *J. Const. Eng. & Manage*., pp. 131-3.
11. Ziara, M., Nigim, K., Enshassi, A. & Ayyub, B. (2002). Strategic implementation of infrastructure priority projects: Case study in Palestine. *Journal of Infrastructure Systems, ASCE*, pp. 8-1.
12. Liu, M. & Ling, Y.Y. (2005). Modeling a contractor's markup estimation. *Journal of Construction Engineering and Management, ASCE*, Vol. 131, No. 4, pp. 391-399.
13. Rashidi, A., Jazebi, F. & Brilakis, I. (2011). Neuro-Fuzzy Genetic System for Selection of Construction Project Managers. *Journal of Construction Engineering and Management, American Society of Civil Engineers*, Vol. 137, Issue 1.

14. Torfi, F. & Rashidi, A. (2011). Selection of project managers in construction firms using AHP and fuzzy TOPSIS: A case study. *Journal of Construction in Developing Countries*. Vol. 16, Issue 1.
15. Abbasianjahromi, H. & Rajaie, H. (In Press). A framework for subcontractor selection in the construction industry. *Journal of Civil Engineering and Management*.
16. Vergara, A. J. (1997). Probabilistic estimating and applications of portfolio theory in construction. PhD thesis, Univ. of Illinois at Urbana-Champaign, Urbana.
17. Kangari, R. & Boyer, L. T. (1981). Project selection under risk. *J. Constr. Div., Am. Soc. Civ. Eng*., Vol. 107, No. 4, pp. 597–608.
18. Kangari, R. & Riggs, L. S. (1988). Portfolio management in construction. *Construction Management and Economics*. pp. 161-169.
19. Han, S. H. (1999). Risk-based Go/No-Go decision making model for international construction projects: The Cross-impact analysis approach. PhD Thesis. Univ. of Colorado at Boulder. Boulder, Colo.
20. Veshosky, D. (1994). Portfolio approach to strategic management of A/E firms. *ASCE Journal of Management in Engineering*. Vol. 10, No. 5.
21. Olsson, R. (2008). Risk management in a multi-project environment an approach to manage portfolio risks. *International Journal of Quality & Reliability Management*, Vol. 25 No. 1. pp. 60-71.
22. Ravanshadnia, M., Rajaie, H. & Abbasian H. R. (2011). A comprehensive bid/no-bid Decision Making Framework for Construction Companies, *Iranian Journal of Science and Technology, Transaction B: Engineering*, Vol. 35, No. B1.
23. Watson, I. (1997). *Applying case-based reasoning: Techniques for enterprise systems*. Morgan Kaufmann Publishers.
24. Maher, M. L. & Balachandran, B. (1994). Multimedia approach to case-based structural design. *J. Comput. Civil Eng.*, Vol. 8. No. 3, pp. 359–76.
25. Morcous, G., Rivard, H. & Hanna, A. M. (2002). Case-based reasoning system for modeling infrastructure deterioration. *J. Comput. Civil Eng., ASCE*, Vol. 16, No. 2, pp. 104–14.
26. Khanum, A., Mufti, M., Younus Javed, M. & Zubair Shafiq, M. (2009). Fuzzy case-based reasoning for facial expression recognition. *Fuzzy Sets and Systems*, Vol. 160, pp. 231–250.
27. Faez, F., Ghodsypour, S.H. & Brien, C.O. (2009). Vendor selection and order allocation using an integrated fuzzy case-based reasoning and mathematical programming model. *Int. J. Production Economics*, pp. 395-408.
28. Aamodt, A. & Plaza, E. (1994). Case-based reasoning: foundational issues, methodological variations and system approaches. *AI Communications*, Vol. 7, No. 1, pp. 39–59.
29. Tabesh, M. & Dini, M. (2010). Fuzzy and neuro-fuzzy models for short-term water demand forecasting in Tehran. *Iranian Journal of Science and Technology, Transaction B: Engineering*, Vol. 33, No. B1.
30. Kolodner, J. L. (1993). *Case-based reasoning*. California: Morgan Kaufmann.
31. Deng, Y., Shi, W., Du F. & Liu Q. (2004). A new similarity measure of generalized fuzzy numbers and its application to pattern recognition. Pattern Recognition Letters, Vol.25, pp. 875-883.
32. Kahraman, C. (2008). Fuzzy multi-criteria decision making theory and applications with recent development. Springer Science, New York.
33. Sargent, R. G. (1984). A tutorial on verification and validation of simulation models. In: S. Sheppard, U. Pooch and D. Pegden (Editors), *Proceedings of the 1984 Winter Simulation Conference*, IEEE 84CH2098-2, pp. 115-122.
34. Balci, O. (1994). Validation, verification, and testing techniques throughout the life cycle of asimulation study. *Annals of Operations Research*, Vol. 53, pp. 121-173.
35. Ravanshadnia, M., Rajaie, H. & Abbasian, H. R. (2010). Hybrid fuzzy MADM project-selection model fordiversified construction companies. *Canadian Journal of Civil Engineering*, Vol. 37, pp. 1082-1093.