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Selecting the Construction Projects Using Fuzzy VIKOR Approach

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ABSTRACT

The purpose of this paper is to introduce a quantitative method for assisting contractors to select appropriate projects for bidding by considering multiple attributes and integrating decision group members opinions. The VIKOR method was developed to solve multiple criteria decision making (MCDM) problems with conflicting or non-commensurable criteria. This method assumes that compromising is acceptable for conflicting resolution. A numerical example is proposed to illustrate an application of the proposed method. In this paper we ranked criteria for construction projects of (Tan , et al ., 2010) with fuzzy VIKOR method.

KEYWORDS: Fuzzy VIKOR, Decision making, Multiple criteria decision making (MCDM), Construction project

1. INTRODUCTION

The construction business is risky. However, construction projects are perceived to have more inherent risks due to the involvement of many contracting parties such as stakeholders, designers, contractors, subcontractors, suppliers, etc. Construction projects are unique and built only once. They also involve a temporary project team that is assembled from different companies, place and etc. Moreover, the size and complexity of construction projects are increasing which adds to the risks. This is in addition to the political, economic, social conditions where the project is to be undertaken. Project risk can be defined as an uncertain event or condition that, if it occurs, has a positive or negative effect on at least one project objective, such as time, cost, quality (Zavadskas , et al., 2008).

Research of this kind, specific to the construction sector, is needed and timely due to the risk associated with construction projects and their ability to cause organization-wide collapse exacerbated by increases in complexity, globalization and technology. To help to manage this risk, widespread change in the sector's approach to career development of practitioners operating outside of the traditional hierarchy (Madter, et al ., 2011). Mega construction projects are usually described as substantial investment (more than 1 billion dollars) long schedule (over two years) public infrastructures, which usually have long life time of 50 years and more, and generate multiple social impact and invested or commissioned by governments. In addition, some projects which have large scale or complex technology, such as underground civil engineering, industry plant construction and so on, are considered as Mega construction projects, due to their complexity on project implementation, integration on project management and consideration on operating during the process of design and construction phase . Mega construction projects bring great difficulties and challenges to project management (Sun, et al., 2011) .Construction projects generally have highly complicated situations during execution, involve many project stakeholders and interfaces, and are influenced by many external factors. Therefore, schedule delays in construction projects are common and affect total project duration in unpredictable ways. Delay information and evidence are usually recorded and represented in different records, documents and schedules during the construction phase. Selecting a suitable delay analysis method and analyzing delay information accurately are essential tasks in any delayed construction project. Current delay analysis methods analyze delay liabilities based on delay information and evidence (Yang , et al ., 2011).

Construction projects shape the built environment in which people live and work. The built environment is typically a country's most important asset, both economically and socially. For advanced countries around 95% of people work in the built environment, where they generate around 80% of GDP . The performance of construction projects and the whole-of life management of constructed assets influences a country's productivity, competitiveness, living quality and ecological sustainability .Yet many countries face significant challenges with the performance of construction projects and constructed assets .The use of financial incentives in construction projects is seen as a key means of improving built environment outcomes. Financial incentives are typically used on construction projects to invigorate motivation towards above business-as-usual (BAU) goals and provide the contractor with the opportunity for higher profit margins if exceptional performance is achieved. BAU includes the mandatory minimum requirements that are to be delivered under the construction contract (Rose , et al ., 2011).

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Repetitive construction projects are quite common in the construction industry, and may be divided into two categories :(1) projects that are repetitive due to a uniform repetition of a unit work throughout projects (multiple similar houses, high rise building); (2) projects that are repetitive due to their geometrical layout (highways, tunnels, pipelines). Repetitive construction projects often require resources (e.g., crews) to perform the same work in various units (locations, segments) by moving from one unit to the next unit in the project Because of this frequent resource movement, an effective schedule is important to ensure the uninterrupted usage of resources of repetitive activities between units (Long. et al., 2009).

The reminder of this paper is organized as follow. Section 2 presents a literature review of construction projects. Fuzzy VIKOR is described in section 3. In section 4 a numerical example is illustrated and finally section 5 concludes the paper.

1. LITERATURE REVIEW

The term construction is generally used to describe the activity of the creation of physical infrastructure, superstructure and related facilities . Construction is also referred to as all types of activities associated with the erection and repair of immobile structures and facilities (Bin Ibrahim , et al., 2010).

A construction project is a complex process that involves many stakeholders, long project durations and complex contractual relationships. Projects can be a tangible outcome that are of finite-duration or those that do not exist in any concrete or conceptual sense (Oyegoke, et al ., 2009).

A major part of activities performed in construction organizations deal with planning, executing, coordinating, and controlling projects, e.g. building new structures Unfortunately, many construction projects do not meet their targets due to poor quality of management practices (Zwikael., 2009). In seeking to improve project delivery processes and outputs of the construction industry, culture is an important consideration . It has been suggested for instance that culture has an influence on the propensity for litigation , and the attitudes and behaviors towards such aspects as health and safety (Ankrah , et al ., 2009).

Construction projects often undergo project delays, cost overruns and non-conformance to quality, leading to poor performance and dissatisfied parties (for example see .Egan , for example, laments that:. . more than a third of major clients are dissatisfied with contractors' performance in keeping to the quoted price and to time, resolving defects, and delivering a final product of the required quality. . . . more than a third of major clients are dissatisfied with consultants' performance in coordinating teams, in design and innovation, in providing a speedy and reliable service and in providing value for money. An understanding of the driving forces behind such problems is a priority if the performance of the industry is to be improved. Unexpected change, which occurs throughout the design and construction phase, hinders project success to a significant degree . Changes of this nature can lead to time overruns, cost overruns and quality deviations. The major cost due to change is the expense of rework and this can amount to 10-15 per cent of contract value . Indirect effects of change are also considerable. Bower identifies examples of indirect effects, including loss of productivity, interruption to workflows and cash flows, which, in turn, may lead to lower moral, claims and disputes between the parties. The appropriate management of change is, thus, essential to the minimization of the disruptive effects of change in construction projects. In construction projects, problem solving often takes place in team environments . According to "construction is a collaborative activity – only by pooling the knowledge and experience of many people can buildings meet the needs of today, let alone tomorrow." (Senaratne , et al ., 2009). In today's dynamic, high-velocity social and business environment, which is characterized by discontinuity and continuous change, crises are understood as more the norm rather than exception in organizations. Manager increasingly realized that "anytime you are not in a crisis, you are instead in a pre-crisis or a prodromal mode" . Construction is typically a complex, crisis-prone activity carried out in an environment which is relatively uncontrollable compared to many manufacturing industry (Zhong , et al ., 2009). In many different aspects, construction holds the key to the prosperity of emerging and industrialized countries. It is the world's largest and most challenging industry and also a large user of national resources and accounts for a sizeable proportion of gross domestic product (GDP) of most developed and developing countries Typically, in developed European countries, for example, construction might account for 10 per cent of the GDP and even higher in many developing countries . The "VIKOR" method was introduced a s an applicable technique to implement within MCDM. It focuses on ranking and selecting from a set of alternatives in the presence of conflicting criteria. Practical problems are often . A compromise solution for a problem with some conflicting criteria can help DM storeach a final decision. The compromise solution, whose foundation was established by Yu and Zeleny, is a feasible solution, which is the closest to the ideal , and here " compromise " means an agreement established by mutual concessions. The VIKOR method deter mines the compromise ranking list and the compromise solution by introducing the multi criteria ranking index based on the particular measure of " closeness " to the " ideal " solution .The multi criteria measure for compromise ranking is developed from the Lp - metric used as an aggregating function in a compromise programming method (Mawdesley, et al ., 2010).

VIKOR method focuses on ranking and selecting from a set of alternatives, and determines compromise solutions for a problem with conflicting criteria, which can help the decision makers to reach a final decision (Opricovic, et al ., 2006).

VIKOR is a compromise decision making method in multi-criteria environments. This technique ranks the alternatives based on two measures: the utility measure (the weighted the ideal solution) and the regret measure (the weighted distance from the negative-ideal solution). The VIKOR index for each alternative is calculated from these measures. The alternative with the least VIKOR index is the best alternative, as it has the maximum group utility and the least regret (Ahmadi, et al ., 2010).

A MADM problem is to find a best compromise solution among all feasible alternatives assessed on the basis of multiple attributes, both quantitative and qualitative. Such problems can be dealt with using several existing methods such as VIKOR (VlseKriterijuska Optimizacija I Komoromisno Resenje) and TOPSIS (technique for order preference by similarity to ideal solution) methods, which are well known MADM methods, developed by Opricovic and Hwang and Yoon, respectively. The VIKOR and TOPSIS methods are both based on an aggregation function representing “closeness to the ideal”.

The VIKOR method introduces the ranking index based on the particular measure of “closeness” to the ideal solution. In contrast, the basic principle of the TOPSIS method is that the chosen alternative should have the “shortest distance” from the positive ideal solution (PIS) and the “farthest distance” from negative ideal solution (NIS). The VIKOR method is a compromise ranking approach for multiple criteria decision making (MCDM) problems. It determines a compromise solution, providing a maximum utility for the majority and a minimum regret for the opponent. There exists a large amount of literature involving VIKOR theory and application. For example, Opricovic and Tzeng , suggested using fuzzy logic for the VIKOR method. Tzeng et al. used and compared the VIKOR and TOPSIS methods in solving a public transportation problem. Büyüközkan and Ruan extended the VIKOR method to effectively solve software evaluation problem under a fuzzy environment. Opricovic and Tzeng extended the VIKOR method with a stability analysis determining the weight stability intervals and with trade-offs analysis and compared the extended VIKOR method with three multi criteria decision making methods: TOPSIS, PROMETHEE, and ELECTRE. Sayadi et al. extended the VIKOR method to MADM problem with interval numbers (Park , et al ., 2011).

3. VIKOR method

Opricovic, Opricovic and Tzeng developed VIKOR, the Serbian name: VlseKriterijumska Optimizacija I Kompromisno Resenje. The VIKOR method was developed for multi-criteria optimization of complex systems. This method focuses on ranking and selecting from a set of alternatives, and determines compromise solutions for a problem with conflicting criteria, which can help the decision makers to reach a final decision. Here, the compromise solution is a feasible solution which is the closest to the ideal, and a compromise means an agreement established by mutual concessions . It introduces the multi-criteria ranking index based on the particular measure of ‘‘closeness” to the ‘‘ideal” solution .

According to the multi-criteria measure for compromise ranking is developed from the PLp-metric used as an aggregating function in a compromise programming method . The various J alternatives are denoted as a1; a2; . . . ; aJ. For alternative aj, the rating of the i th aspect is denoted by fij , i.e. fij is the value of i th criterion function for the alternative aj; n is the number of criteria. Development of the VIKOR method started with the following form of Lp-metric:

$$L_{pj} = \left\{ \sum_{i=1}^{n} \left[w_i (f_i^* - f_{ij})(f_i^* - f_i^-) \right]^p \right\}^{1/p} \quad (1)$$

$$1 \le p \le \infty; \quad j = 1,2,...,J$$

The main steps of the fuzzy VIKOR are:

1. Determine the aim of decision making process and problem scope.
2. Identify experts of decision making field and set relevant attributes.
3. Identify the appropriate linguistic variables

In this step any linguistic variables can be used. Triangular of trapezoidal fuzzy numbers can be applied for rating alternatives with regard to each criterion. In this paper, positive trapezoidal fuzzy numbers are used, as in table 1.

Table1: Linguistic terms describing attribute weightings and ratings

Linguistic terms		
Weighting	**Ratings**	**Triangular fuzzy numbers**
Very Low(VL)	Very poor(VP)	(0,0,0.1,0.2)
Low(L)	Poor(P)	(0.1,0.2,0.2,0.3)
Medium low(ML)	Medium Poor (MP)	(0.2,0.3,0.4,0.5)
Medium(M)	Fair (F)	(0.4,0.5,0.5,0.6)
Medium High(MH)	Medium good (MG)	(0.5,0.6,0.7,0.8)
High(H)	Good(G)	(0.7,0.8,0.8,0.9)
Very High(VH)	Very good (VG)	(0.8,0.9,1,1)

4. Obtain the decision makers' viewpoints to get aggregated fuzzy weight of criteria, and aggregated fuzzy rating of alternatives and construct a fuzzy decision matrix.

Suppose that the fuzzy rating of the k[th] decision maker be $\tilde{x}_{ijk} = (x_{ijk1}, x_{ijk2}, x_{ijk3}, x_{ijk4})$ and importance weight of the k[th] decision maker be $\tilde{w}_{jk} = (\tilde{w}_{jk1}, \tilde{w}_{jk2}, \tilde{w}_{jk3}, \tilde{w}_{jk4})$; i=1,2,…,m , j=1,2,…,n. Therefore, the aggregated fuzzy ratings $(\tilde{x}_{ij})$ of alternatives with respect to each criterion can be computed as:

$\tilde{x}_{ij} = (x_{ij1}, x_{ij2}, x_{ij3}, x_{ij4})$ Where

$$x_{ij1} = \min_k \{x_{ijk1}\} \;,\; x_{ij2} = \frac{1}{k}\sum_{k=1}^{k} x_{ijk2} \;,\; x_{ij3} = \frac{1}{k}\sum_{k=1}^{k} x_{ijk3} \;,\; x_{ij4} = \max_k \{x_{ijk4}\} \qquad (2)$$

The aggregated fuzzy weights $(\tilde{w}_j)$ of each criterion can be computed as:

$\tilde{w}_j = (w_{j1}, w_{j2}, w_{j3}, w_{j4})$ Where

$$w_{j1} = \min_k \{w_{jk1}\} \;,\; w_{j2} = \frac{1}{k}\sum_{k=1}^{k} w_{jk2}, \;,\; w_{j3} = \frac{1}{k}\sum_{k=1}^{k} w_{jk3} \;,\; w_{j4} = \min_k \{w_{jk4}\} \qquad (3)$$

In this sense, a construction projects selection problem can be concisely presented in matrix format as follows:

$$\tilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ & & . & \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \;,\; \tilde{W} = [\tilde{w}_1 \quad \tilde{w}_2 \quad \cdots \quad \tilde{w}_n] \qquad (4)$$

Defuzzify the fuzzy decision matrix ($\tilde{D}$) and fuzzy weight ($\tilde{W}$) of each criterion into crisp values.

5. Determine the best f_j^* and the worst f_j^- values of all criteria ratings as follow, j=1,2,..,n

$$f_j^* = \max_i x_{ij}; \quad , \quad f_j^- = \min_i x_{ij}; \qquad (5)$$

6. Calculate the values of S_i and R_i by the equations (6), (7) respectively.

$$S_i = \sum_{j=1}^{n} w_j (f_j^* - f_{ij})(f_i^* - f_i^-) \qquad (6)$$

$$R_i = \max_j \; w_j (f_j^* - f_{ij})(f_i^* - f_i^-) \qquad (7)$$

7. Compute the values Q_i by the relations

$$Q_i = v(S_i - S^*)/(S^- - S^*) + (1+v)(R_u - R^*)/(R^- - R^*) \qquad (8)$$

Where

$$S^* = \min S_i \;,\; S^- = \max S_i \;,\; R^* = \min R_i \;,\; R^* = \max R_i \qquad (9)$$

and v is the weight of the strategy of maximum group utility. Whereas 1-v is the weight of the individual regret.

8. By sorting alternatives with the values S,R and Q in ascending order, rank the alternatives.
9. Identify as a compromise solution the alternative $(A^{(1)})$ which is the best ranked by the measure Q (minimum) if the following two conditions are met.

C1. Acceptable advantage:

$$Q(A^{(2)}) - Q(A^{(1)}) \geq DQ \qquad (10)$$

Where $A^{(2)}$ is the alternative with second position in the ranking list by Q; DQ=1/(J-1).

C2. Acceptable stability in decision making:

The alternative $A^{(1)}$ must also be the best ranked by S or/and R.

This compromise solution is stable within a decision making process, which could be the strategy of maximum group utility (when v >0.5 is need), or "by consensus" $v \approx$ 0.5 or "with veto" (v <0.5).

If one of the conditions is not met , then a set of compromise solutions is proposed , which consists of

- Alternatives $A^{(1)}$ and $A^{(2)}$ if only the condition C2 is not satisfied, or

- Alternatives $A^{(1)}$, $A^{(2)}$, …. $A^{(M)}$ if the condition C1 is not satisfied; $A^{(M)}$ is determined by the relation $Q(A^{(1)}) < DQ$ for maximum M (the positions of these alternatives are "in closeness") (Sanayei , et al ., 2010).

4. Numerical example

The data of this paper are extracted from (Tan , et al ., 2010) and authors have ranked construction projects using TOPSIS. Here, we solve that problem using fuzzy VIKOR. The nine criteria were used are profitability (G1), difficulty (G2), relationship with owner (G3), need for work (G4), resources and capabilities (G5), keenness of competitors (G6), competitors' competitiveness (G7), project execution risk (G8) and financial risk (G9), where the unit adopts a 0 to 1 scale. G2, G6, G7, G8 and G9 are cost criteria, and the other four criteria are benefit criteria. . Tables 2-7 show the score of each criterion and alternative and results of fuzzy VIKOR.

Table2 : Importance weight of criteria from three decision makers.

criteria	Decision makers		
	D_1	D_2	D_3
G_1	H	H	VH
G_2	M	MH	M
G_3	H	H	MH
G_4	H	MH	M
G_5	VH	H	H
G_6	M	MH	MH
G_7	H	H	H
G_8	H	MH	MH
G_9	M	H	H

Table3: Ratings of the three construction projects by the decision makers under the various criteria.

Decision makers		Criteria								
		G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	G_9
D_1	x_1	VG	MG	F	F	G	G	G	MG	MG
	x_2	F	F	F	G	F	MG	G	F	F
	x_3	F	MG	F	MG	MG	F	F	F	F
D_2	x_1	VG	F	F	F	MG	F	MG	MG	F
	x_2	F	F	F	MG	F	MG	MG	F	MG
	x_3	MG	F	F	MG	MG	F	F	F	F
D_3	x_1	G	MG	F	MG	MG	MG	MG	MG	F
	x_2	MG	MG	MP	G	F	MG	F	MG	MG
	x_3	F	F	MG	MG	MG	F	F	F	F

Table 4: Criteria: Aggregated fuzzy weight of criteria and Aggregated fuzzy rating of alternatives.

	fuzzy weight	x_1	x_2	x_3
G_1	(0.7,0.83,0.87,1)	(0.7,0.86,0.93,1)	(0.4,0.53,0.57,0.8)	(0.4,0.53,0.57,0.8)
G_2	(0.4,0.53,0.57,0.8)	(0.4,0.57,0.63,0.8)	(0.4,0.53,0.57,0.8)	(0.4,0.53,0.57,0.8)
G_3	(0.5,0.73,0.77,0.9)	(0.4,0.5,0.5,0.6)	(0.2,0.43,0.47,0.6)	(0.4,0.53,0.57,0.8)
G_4	(0.4,0.63,0.67,0.9)	(0.4,0.53,0.57,0.8)	(0.5,0.73,0.77,0.9)	(0.5,0.6,0.7,0.8)
G_5	(0.7,0.83,0.78,1)	(0.5,0.67,0.73,0.9)	(0.4,0.5,0.5,0.6)	(0.5,0.6,0.7,0.8)
G_6	(0.4,0.57,0.63,0.5)	(0.4,0.63,0.67,0.6)	(0.5,0.6,0.7,0.5)	(0.4,0.5,0.5,0.6)
G_7	(0.5,0.67,0.73,0.9)	(0.5,0.67,0.73,0.9)	(0.4,0.63,0.67,0.9)	(0.4,0.5,0.5,0.6)
G_8	(0.5,0.67,0.73,0.9)	(0.5,0.6,0.7,0.81)	(0.4,0.53,0.57,0.8)	(0.4,0.5,0.5,0.6)
G_9	(0.5,0.73,0.77,0.9)	(0.4,0.53,0.57,0.8)	(0.4,0.57,0.63,0.8)	(0.4,0.5,0.5,0.6)

Table5: Crisp values for decision matrix and weight of each criterion.

	Weight	x_1	x_2	x_3
G_1	0.85	0.87	0.77	0.77
G_2	0.57	0.6	0.57	0.77
G_3	0.72	0.5	0.57	0.57
G_4	0.65	0.57	0.79	0.65
G_5	0.85	0.7	0.5	0.65
G_6	0.6	0.65	0.87	0.67
G_7	0.8	0.7	0.65	0.5
G_8	0.7	0.65	0.57	0.5
G_9	0.72	0.57	0.6	0.6

Table6: The values of S,R and Q for all construction projects.

	X1	X2	X3
S	3.77	3.95	3.75
R	0.72	0.85	0.8
Q	0.95	0	0.69

Table7: The ranking of the construction projects by S,R and Q in decreasing order

Rank		1	2	3
By	S	x_3	x_1	x_2
By	R	x_1	x_3	x_2
By	**Q**	x_2	x_3	x_1

In this paper we ranked criteria of projects based on S is as same as the ranking of (Tan et al. 2010) for construction projects with fuzzy VIKOR and our results show that x_3 is the best choice.

5. Conclusion

Construction is an information-intensive process involving diverse project partners. The primary responsibility of design is to specify project information in detail enabling its construction and to satisfy the client's requirements as well .At the construction stage, the design information is translated into a physical facility. Construction projects are managed by designated project managers, architects, or contractors on behalf of the client or by the clients themselves depending upon the contract and the project type. Effective communication is important to monitor and control projects' activities according to the project plans and for achieving project goals. Construction projects require effective collaboration and coordination among the diverse project participants. It can be achieved by effective communication between all the project participants. Such co-ordination and effective communication is crucial in order to achieve quality standards and to reduce the cost of production effectively.

The project selection problem is often influenced by uncertainty in practice, and in such situation fuzzy set theory is an appropriate tool to deal with this kind of problems. In this paper an extension of the VIKOR, a recently introduced MCDM method, in fuzzy environment is proposed to deal with the both qualitative and quantitative criteria and select the suitable projects effectively.

Since the fuzzy VIKOR method is concise and practical, it is suitable to take this job and other methods may be used to consolidate the results from the fuzzy approach. Nevertheless, the final decision still rests with upper management.

The proposed method is very flexible. Using this method not only enables us to determine the outranking order of projects, but also assess and rate the projects. These rating can be used in combination with mathematical programming and other methods to deal with project selection in multiple sourcing environments. In this paper, trapezoidal fuzzy numbers were used for ranking projects. Future researches can use triangular fuzzy numbers for this purpose. The most challenging issue in MCDM techniques like VIKOR is that when the number of alternatives is high, ranking them may be problematic. Therefore researchers must pay more attention on this issue.

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