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A Five-Point-Scale Group Fuzzy-TOPSIS Contractor Selection Model Considering Minimum Expectations

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Abstract

In construction, owners (clients) are expected to set budget and time limits for their construction projects. In addition, and prior to tendering, experienced project manager(s) set the minimum anticipated quantitative and qualitative qualities that qualify a contractor to successfully finish the project. This paper demonstrates the impact of evaluating contractor's qualities against minimum expectations on the likelihood of selecting that contractor for the tender. The paper employs a five-point scale Fuzzy-TOPSIS technique to demonstrate the impact of uncertainties in selecting among contractors. The study employs only benefit and cost criteria with considerable importance to the decision maker. Thirty-six experimental scenarios were conducted and the closeness coefficient of five contractors were recorded. Results obtained from the study show various impacts of the study parameters on the final selection of the contractor. Among the many results obtained, several experiments qualify a contractor with "as expected" qualities over others with several superior qualities. This comes as a result of avoiding over rating qualities beyond the expected sufficient levels to successfully complete the project while, at the same time, largely penalizing qualities under the expected levels.

Keywords: Contractor Selection, Tender, MCDM, AHP, TOPSIS.

1. Introduction

Multiple criteria decision making (MCDM) finds many applications in industry and services including the selection of equipment [1], components [2], materials [3], processes [4] and technology [5]. Moreover, MCDM techniques found applications in the selection of training programs [6], contractors [7], and suppliers [8]. and in risk assessment [9]. Construction projects vary in size and complexity, and accordingly, contractors must have sufficient number of skilled manpower and machinery to perform the job right and on time. Therefore, the contractor selection process involves evaluating contractors over various financial, technical and non-technical criteria to ensure the "better" performance throughout the project. In construction, project owners are required to set time, quality and cost limits, usually with slacks, on their projects. Given clients' requirements, project engineers and/or project managers utilize their experiences to set minimum limits on various technical and non-technical criteria that qualify a contractor to successfully complete the project. Consequently, the contractor selection process is a MCDM process that may yield different decisions based on the used MCDM method. The MCDM evaluation process includes settling the selection criteria, determining the level of importance for criteria, and finally evaluating the collective score of each contractor against criteria [7].

Tendering is a widely used method to invite contractors to compete for the project. To ensure transparency and liability, project owners are obligated to inform contractors about the process by which tenders will be qualified and selected. Therefore, project owners are required to provide adequate documents that detail desired requirements. Accordingly, intent contractors are expected to provide sufficient information of professional capabilities to ensure compliance to requirements. Submitted tender documents are then cross-examined, by project managers, against requirements and against one-another and the most appropriate contractor is selected [10]. The involvement of project managers from different backgrounds (financial, technical, and others), their different degrees of influence on the decision, and their rather vague subjective judgements on documents introduce added complexity to the selection process. Therefore, fuzzy logic is widely proposed by researchers to incorporate the various forms

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of uncertainties in interpreting unclear information and in the decision-making process in general[11].

Prior to evaluating tenders, decision makers tend to set the minimum qualities that qualify a contractor to successfully complete the project. In addition, decision makers set the maximum obligations (costs) that the project owners can bear. Consequently, if all tenders are below expected qualities or if all tenders are above expected costs, all contractors may be disqualified and the tendering process starts over. In addition, decision makers may select a contractor with lower qualities over another with superior qualities if their associated costs are lower. For example, if the minimum number of years in business is set at 3 years, decision makers may evaluate a contractor with 4 years of experience and another with 10 years of experience as equal or slightly advantage the latter. Consequently, decision makers may qualify the less experienced contractor if they pose less obligations on the project owners. On the contrary, a comparison between the two contractors may much favor the latter contractor for the many more years of experience. Figure 1 outlines the flow of the selection process among contractors; tendering, prequalification and the selection. Following tendering, decision makers screen tender documents to advance contractors with the potential to prevail. At this stage, decision makers may be tolerant to some criteria if the contractor shows superior qualities in other criteria. In the selection stage, decision makersgo through the rather lengthy process to select the "right" contractor which necessitates the use of MCDM techniques.

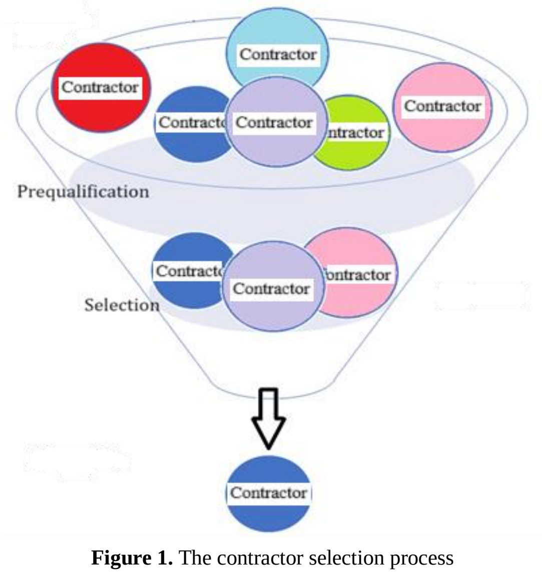

Figure 1. The contractor selection process

This study combines Fuzzy logic with the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to advantage from the flexibility of fuzzy rating and the ability of TOPSIS in handling large scale selection problems. The study presents a multi-expert multi-criteria Fuzzy-TOPSIS model for selecting among contractors based on their qualities presented in tender documents. Given minimum tendering requirements as decision criteria,each tender is evaluated based on the degree of compliance of the submitted proof of qualification to each requirement. The study aims to investigate the impact of accounting for pre-set minimum limits on decision criteria on the chances that a contractor is selected.

This study contributes theoretically and practically to the literature by providing alternative bases for the contractor evaluation and selection process. The proposed model utilizes a five-point fuzzy evaluation to capture a wide range uncertainties among the stakeholders of the project. At the criteria level, the five-point fuzzy scale allows for a distinct differentiation between the importance of criteria. The model calls for accounting for few most important criteria only. To govern bias while judging contractors against selection criteria, the model calls for pre-setting expected (minimum/maximum)quality/cost for each benefit/cost criterion that qualify a contractor to successfully complete the project. The model proposes a five-point fuzzy scale to evaluate each contractor against the pre-set limit. While the scale penalizes largely contractors with inferior qualities/costs, the model does not significantly rewards contractors with superior qualities/costs. This prevents the project manager from overpaying for unusable qualities. To sum up, the study proposes a model that governs bias in the individual evaluations and the joint disagreements among project stakeholders. Moreover, the study provides a practical perspective through applying various decision-making scenarios to illustrate the impact of pre-set limits on the performances of the contractors.

The remainder of this paper is structured as follows. Section 2 provides a review on the literature on contractor selection. Section 3 presents the Fuzzy-TOPSIS model. The application of the model to a case-study is presented in Section 4. Finally, section 5 provides concluding remarks.

2. Literature Review

Over the years, construction industry has widely grown to enhance and connect civilizations. Construction is considered one of direct measures of the progress and the prosperity of any nation. Although "good" planning for construction is vital, project execution is the core activity of the construction project. Therefore, selecting an appropriate construction contractor is key to the successful execution of the construction project. To enhance contractor's performance and to minimize the risk of their failure, project owners and managers set minimum requirements for contractors to self-prequalify before they bid. The rather subjective nature of requirements and the inherited tradeoffs among requirements leave room for contractors to show evidences of their capabilities to complete the project as required. Consequently, project managers must utilize their experiences in evaluating submitted proofs and in qualifying the most appropriate contractor. These decisions are of multi-criteria in nature and, hence, call for a MCDM method to aid decision makers select among contractors.

In the literature, researchers applied combinations of MCDM methods to support and facilitate the decision-making process. Common MCDM under certainty methods include Analytical Hierarchy Process (AHP) and TOPSIS for independent criteria, and Analytical Network Process (ANP) for dependent criteria. For MCDM under uncertainty, Fuzzy logic is commonly used to handle uncertainties[12].Other MCDM techniques used in literature include Additive Ratio Assessment (ARAS), Evaluation Based on Distance from Solution (EDAS), Grey Relation Analysis (GRA), Complex Proportional Assessment (COPRAS), and Criteria Importance through Inter-Criteria Correlation (CRITIC)[2]. Among the many MCDM techniques, Fuzzy-TOPSIS finds the candidate closest to the fuzzy positive ideal solution (FPIS) and farthest from the fuzzy negative ideal solution (FNIS) [13]. Fuzzy-TOPSIS allows the decision maker to use linguistic valuations instead of static numerical values hard to estimate with certainty. Given the linguistic assessments for the qualitative and quantitative criteria, the Fuzzy-TOPSIS technique estimates the normalized weights of criteria, and finds the normalized scores of FPIS, FNIS and candidates. For each candidate, the technique computes the distance between that candidate and the FPIS, and it computes the distance between the candidate and the FNIS. Finally, Fuzzy-TOPSIS computes closeness coefficient for each candidate, and the candidate with best-combined score is selected [14].Sabaneh et. al [15] discussed the impact of mixing evaluation methods on the final selection of contractors when TOPSIS is used. The study focused on the importance of consistent evaluations; i.e. not mixing relative evaluations used in AHP with crisp ones used in TOPSIS.

Several criteria are proposed in the literature to prequalify a construction contractor with technical and financial capability and past experience most common. In [16], the authors identified several qualifying factors for the selection including past performance (type, size and quality of previous projects), technical aspects (available human and equipment resources), and financial capacity. Darvish et al. [17] used work experience and reputation, availability of equipment and technology, qualifications and experience of professional staff, domestication and financial stability. In addition to previously mentioned criteria, Jaskowsk et al. [18] used organizational experience in safety policy and quality system. Moreover, Lam and Yu [19] used current workload, environmental concern, and complaint history. In [20], Mahdi et al. used criteria included access to the workforce and equipment, business strategy, logistic capability and scheduling, and work guarantee. Nieto-Morote and Ruz-Vila [21] focused on financial capability and financial stability, credit and liquidity. Additionally, Singh and Tiong [22]advocated potential performance and project-specific selection criteria. Table 1 shows examples of the benefit and cost criteria used in the past literature. Some of the criteria can be further divided into more than one criterion or into sub-criteria. It is known from the literature that increasing the number of criteria/sub-criteria reduces the effective weight of criteria. One the other hand, the joining of criteria/sub-criteria adds to the uncertainty in providing one weight that better values that criteria.

Several researchers used MCDM techniques in decision-related studies in construction. In addition to previously mentioned literature, Jato-Espino [23] provided a review of literature on the application of twenty-two MCDM techniques, including Fuzzy-TOPSIS, in eleven categories of construction projects. Among the reviewed, Fuzzy-TOPSIS was applied to evaluate and to handle the risks that road, bridge and tunnelling construction projects involve, to assess sustainable transportation systems, and to prequalifying construction contractors. Zhu, Meng and Zhang [24] systematically reviewed 530 articles, published between 2000 and 2019, applying MCDM methods in construction. The authors illustrated that MCDM found applications in almost every aspect of construction decision making ranging from selection decisions to environment assessment. The authors claim that 5.28% of published articles used Fuzzy-TOPSIS. The authors illustrated the need for more robust MCDM methods in the future research. In [25], Fawzy et al. presented a two-phase MCDM model for qualifying a contractor for Egyptian road maintenance. In the first phase, the authors used AHP to obtain the weights of criteria and the associated scores of contractors. The obtained weights and scored are then used in the second phase to select the winning contractor using TOPSIS and VIKOR (VIseKriterijumska Optimizacija I Kompromisno Resenje). Results obtained from the study showed that the winning contractor had the highest project price. Antoniou and Aretoulis[26]applied TOPSIS and the multi attribute utility theory to the problem of deciding the appropriate contract typein construction. The proposed methodology was applied to two pilot highway construction projects in Greece based on nine selection criteria. The author proposed a decision support system to help decision makers decide on the most appropriate contract type in construction. Alptekin and Alptekin [27] used TOPSIS to rank twelve selection criteria in public construction projects in Turkey based on votes of multiple experts from the Department of Construction Works of Eskisehir Osmangazi University. Results showed that "termination of construction work in previous tenders" was the most important criterion while "lowest bid" ranked fifth. Vahdani et al [28]modified a group fuzzy MCDM method for the contractor selection problem considering conflicting criteria. The proposed method builds on TOPSIS and VIKOR techniques while employing fuzzy group decision making. The method was applied to cases in construction industry to demonstrate usability. Nafteh and Shahrokhi [29]presented an improved intuitionistic Fuzzy COPRAS MCDM method for supplier selecting with the objective of enhancing sustainability. The authors detailed an example to illustrate the applicability of the model to real life applications.

Table 1. Contractor selection criteria

Criteria	Document must demonstrate	Benefit/ Cost
Technical capability	Availability of human and equipment resources compared to work load.	Benefit
Financial capacity	Proof of financial capability and stability.	Benefit
Past Experience	Years of experience in the business; Scale of previous projects.	Benefit
Work practices	Organizational experience in managing safety, the environment and quality systems.	Benefit
Domestication	Experience in local area; Involvement of local community.	Benefit
Past performance	Failure to complete contract; Delay; Poor quality; Poor safety performance; Serious client/contractor disputes.	Cost
Financial obligations	Total cost and payment schedule	Cost
Work schedule	Plan of execution (expected time to finish the project)	Cost

3. Methodology

This research used past literature to realize common benefit and cost criteria vital to selecting a construction contractor. In their study, Alshraideh et al. [7] discussed several scenarios for aggregating disagreements among decision makers. Moreover, the authors introduced a model for rating contractors based on pre-set expectations for the various criteria. This study builds on the results obtained in [7] to better capture the effect of disagreement among decision makers while evaluating contractors based on submitted documents against pre-set expectations. To enhance the use of Fuzzy-TOPSIS, *b* benefit criteria (B_1 to B_b) and *c* cost criteria(C_1 to C_c), are realized. Criteria are ranked in a descending order($B_1 \geq B_2 \geq \ldots \geq B_b$ and $C_1 \geq C_2 \geq \ldots \geq C_c$) based on their degree of importance to project owners and decision makers. For each benefit criterion, a number of decision makers examine the contractor's associated quality/capability illustrated in submitted documents against the project's expected level of requirement for that criterion, and for each cost criterion, decision makers examine the contractor's associated requirement illustrated in submitted documents against the expected obligation. Given individual experts' evaluations, Fuzzy-TOPSIS is applied to identify the winning contractor.

To prevent the over-rating of a contractor with qualities way beyond expectations, verbal evaluations are used to indicate the deviation of each criterion from the expected. Table 2 illustrates an example of the verbal evaluations, ordered from worst-to-best, representing ratings of below, within and above expectations on a five-point scale. Moreover, the table shows the associated triangular fuzzy number (TFN), see figure 2 adapted from [7], associated with each verbal evaluation. Notice that the weights of criteria are set assuming that less important criteria are filtered out based on previous agreement between the stakeholders. Moreover, the weights reduce some of the bias among decision makers and keeps a healthier disagreement. For benefit criteria, the proposed evaluations slightly advantage contractors with superior qualities over those within expected qualities since both are expected to complete the project successfully. A similar argument can be associated with cost criteria.

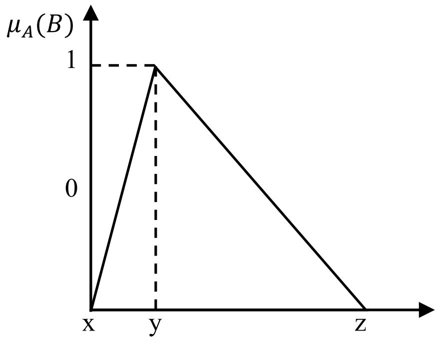

Figure 2. Triangular fuzzy number (TFN) [7]

In Fuzzy-TOPSIS, the TFN membership function $\mu_A(B)$, see figure 2 adapted from [7], is used to characterize fuzzy set A in universe B such that each element in B is associated a real number between 0 and 1 [7]. The Fuzzy-TOPSIS model used in this study is adapted from the literature revised in [7]. For the purpose of this study, detailed steps are omitted since it can be found in [7]. Figure 3 summarizes the work steps of the Fuzzy-TOPSIS model adapted from [7].

4. Analysis, Results, and Discussion

A total of thirty-six experiments are conducted to record the closeness coefficient, CC_i, for five contractors, $CONT_1$ – $CONT_5$, for various experiment scenarios, as shown in Table 3. In the table, see Table 2 for the linguistic evaluations used in the study, numeric weights of criteria are such that 1:ML, 2:MD, 3:MH, 4:HI,and 5:VH. For benefit scores, 1:EBE, 2:BE, 3:WE, 4:AE, and 5:EAE. For cost scores, 1:EAE, 2:AE, 3:WE, 4:BE and 5:EBE.All evaluations in Exp1 through Exp31, Table 3, are based on total agreement among decision makers. Exp32 through Exp36, Table 4, illustrate disagreements among decision makers in both weights and scores.

Table 2. Linguistic evaluations

Weights of criteria		Scores of contractors against benefit criteria		Scores of contractors against cost criteria	
Linguistic variable	TFN	Linguistic variable	TFN	Linguistic variable	TFN
Medium-Low (ML)	(4, 4.5, 5)	Extremely below expected (EBE)	(1, 1, 2)	Extremely above expected (EAE)	(9.5, 10, 10)
Medium (MD)	(5, 5.5, 6)	Below expected (BE)	(1, 2, 2)	Above expected (AE)	(8.5, 9, 9.5)
Medium-High (MH)	(6.5, 7, 7.5)	Within/As expected (WE)	(9, 9, 10)	Within/As expected (WE)	(2, 2, 3)
High (HI)	(8, 8.5, 9)	Above expected (AE)	(9.5, 9.5, 10)	Below expected (BE)	(1, 2, 2)
Very High (VH)	(9, 9.5, 10)	Extremely above expected (EAE)	(9.5, 10, 10)	Extremely below expected (EBE)	(1, 1, 2)

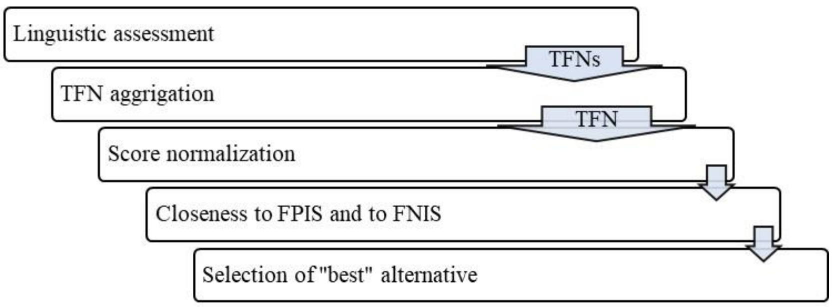

Figure 3. Work steps of Fuzzy-TOPSIS

Table 3. The CC_i for contractors for various scenarios

Experiment	Criteria		Contractor				
Exp1	Criteria	Weight	$CONT_1$	$CONT_2$	$CONT_3$	$CONT_4$	$CONT_5$
	Benefit	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
		CC_i	**1.000**	0.822	0.700	0.041	0.000
Exp2	Criteria	Weight	$CONT_1$	$CONT_2$	$CONT_3$	$CONT_4$	$CONT_5$
	Benefit	5, 5, 5, 5, 5	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost	5, 5, 5, 5, 5	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
		CC_i	**1.000**	0.822	0.701	0.041	0.000
Exp3	Criteria	Weight	$CONT_1$	$CONT_2$	$CONT_3$	$CONT_4$	$CONT_5$
	Benefit	3, 3, 3, 3, 3	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost	3, 3, 3, 3, 3	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
		CC_i	**1.000**	0.822	0.700	0.041	0.000
Exp4	Criteria	Weight	$CONT_1$	$CONT_2$	$CONT_3$	$CONT_4$	$CONT_5$
	Benefit	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	3, 3, 3, 3, 3	3, 3, 3, 3, 3
	Cost	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	3, 3, 3, 3, 3	3, 3, 3, 3, 3
		CC_i	**1.000**	0.784	0.618	0.044	0.000
Exp5	Criteria	Weight	$CONT_1$	$CONT_2$	$CONT_3$	$CONT_4$	$CONT_5$
	Benefit	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost	5, 4, 3, 2, 1	3, 3, 3, 3, 3	3, 3, 3, 3, 3	3, 3, 3, 3, 3	3, 3, 3, 3, 3	3, 3, 3, 3, 3
		CC_i	**1.000**	0.966	0.926	0.066	0.000
Exp6	Criteria	Weight	$CONT_1$	$CONT_2$	$CONT_3$	$CONT_4$	$CONT_5$
	Benefit	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost	5, 4, 3, 2, 1	1, 1, 1, 1, 1	1, 1, 1, 1, 1	1, 1, 1, 1, 1	1, 1, 1, 1, 1	1, 1, 1, 1, 1
		CC_i	**1.000**	0.966	0.926	0.066	0.000
Exp7	Criteria	Weight	$CONT_1$	$CONT_2$	$CONT_3$	$CONT_4$	$CONT_5$
	Benefit	5, 4, 3, 2, 1	3, 3, 3, 3, 3	3, 3, 3, 3, 3	3, 3, 3, 3, 3	3, 3, 3, 3, 3	3, 3, 3, 3, 3
	Cost	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
		CC_i	**1.000**	0.688	0.453	0.013	0.000
Exp8	Criteria	Weight	$CONT_1$	$CONT_2$	$CONT_3$	$CONT_4$	$CONT_5$
	Benefit	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost	5, 4, 3, 2, 1	1, 1, 1, 1, 1	2, 2, 2, 2, 2	3, 3, 3, 3, 3	4, 4, 4, 4, 4	5, 5, 5, 5, 5
		CC_i	0.519	0.511	**0.700**	0.386	0.481
Exp9	Criteria	Weight	$CONT_1$	$CONT_2$	$CONT_3$	$CONT_4$	$CONT_5$
	Benefit	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost	5, 4, 3, 2, 1	4, 4, 4, 4, 4	5, 5, 5, 5, 5	5, 5, 5, 5, 5	5, 5, 5, 5, 5	5, 5, 5, 5, 5
		CC_i	0.747	**0.975**	0.945	0.298	0.253
Exp10	Criteria	Weight	$CONT_1$	$CONT_2$	$CONT_3$	$CONT_4$	$CONT_5$
	Benefit	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost	5, 4, 3, 2, 1	3, 3, 3, 3, 3	4, 4, 4, 4, 4	4, 4, 4, 4, 4	4, 4, 4, 4, 4	4, 4, 4, 4, 4
		CC_i	0.725	**0.976**	0.946	0.318	0.275
Exp11	Criteria	Weight	$CONT_1$	$CONT_2$	$CONT_3$	$CONT_4$	$CONT_5$
	Benefit	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost	5, 4, 3, 2, 1	3, 3, 3, 3, 3	3, 3, 3, 3, 3	4, 4, 4, 4, 4	4, 4, 4, 4, 4	4, 4, 4, 4, 4
		CC_i	0.725	0.704	**0.946**	0.318	0.275
Exp12	Criteria	Weight	$CONT_1$	$CONT_2$	$CONT_3$	$CONT_4$	$CONT_5$
	Benefit	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost	5, 4, 3, 2, 1	2, 2, 2, 2, 2	2, 2, 2, 2, 2	3, 3, 3, 3, 3	2, 2, 2, 2, 2	2, 2, 2, 2, 2
		CC_i	0.550	0.534	**0.959**	0.037	0.000
Exp13	Criteria	Weight	$CONT_1$	$CONT_2$	$CONT_3$	$CONT_4$	$CONT_5$
	Benefit	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost	5, 4, 3, 2, 1	1, 1, 1, 1, 1	1, 1, 1, 1, 1	1, 1, 1, 1, 1	5, 5, 5, 5, 5	1, 1, 1, 1, 1
		CC_i	**0.519**	0.505	0.485	0.509	0.000
Exp14	Criteria	Weight	$CONT_1$	$CONT_2$	$CONT_3$	$CONT_4$	$CONT_5$
	Benefit	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost	5, 4, 3, 2, 1	1, 1, 1, 1, 1	1, 1, 1, 1, 1	1, 1, 1, 1, 1	1, 1, 1, 1, 1	5, 5, 5, 5, 5
		CC_i	**0.519**	0.505	0.485	0.035	0.481
Exp15	Criteria	Weight	$CONT_1$	$CONT_2$	$CONT_3$	$CONT_4$	$CONT_5$
	Benefit	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost	5, 4, 3, 2, 1	2, 2, 2, 2, 2	2, 2, 2, 2, 2	3, 1, 1, 1, 1	2, 2, 2, 2, 2	2, 2, 2, 2, 2
		CC_i	0.829	0.805	**0.885**	0.109	0.058
Exp16	Criteria	Weight	$CONT_1$	$CONT_2$	$CONT_3$	$CONT_4$	$CONT_5$
	Benefit	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost	5, 4, 3, 2, 1	2, 2, 2, 2, 2	2, 2, 2, 2, 2	1, 3, 1, 1, 1	2, 2, 2, 2, 2	2, 2, 2, 2, 2
		CC_i	0.845	0.820	**0.881**	0.112	0.062
Exp17	Criteria	Weight	$CONT_1$	$CONT_2$	$CONT_3$	$CONT_4$	$CONT_5$
	Benefit	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost	5, 4, 3, 2, 1	2, 2, 2, 2, 2	2, 2, 2, 2, 2	1, 1, 3, 1, 1	2, 2, 2, 2, 2	2, 2, 2, 2, 2
		CC_i	0.869	0.843	**0.875**	0.118	0.067
Exp18	Criteria	Weight	$CONT_1$	$CONT_2$	$CONT_3$	$CONT_4$	$CONT_5$

	Benefit	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost	5, 4, 3, 2, 1	2, 2, 2, 2, 2	2, 2, 2, 2, 2	1, 1, 1, 5, 1	2, 2, 2, 2, 2	2, 2, 2, 2, 2
		CC_i	**0.882**	0.856	0.870	0.123	0.071
Exp19	Criteria	Weight	CONT$_1$	CONT$_2$	CONT$_3$	CONT$_4$	CONT$_5$
	Benefit	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost	5, 4, 3, 2, 1	2, 2, 2, 2, 2	2, 2, 2, 2, 2	1, 1, 1, 5, 3	2, 2, 2, 2, 2	2, 2, 2, 2, 2
		CC_i	0.810	0.787	**0.889**	0.105	0.056
Exp20	Criteria	Weight	CONT$_1$	CONT$_2$	CONT$_3$	CONT$_4$	CONT$_5$
	Benefit	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost	5, 4, 3, 2, 1	2, 2, 2, 2, 2	2, 2, 2, 2, 2	1, 1, 1, 3, 5	2, 2, 2, 2, 2	2, 2, 2, 2, 2
		CC_i	0.812	0.788	**0.889**	0.105	0.056
Exp21	Criteria	Weight	CONT$_1$	CONT$_2$	CONT$_3$	CONT$_4$	CONT$_5$
	Benefit	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost	5, 4, 3, 2, 1	2, 3, 3, 3, 3	3, 3, 3, 3, 3	3, 3, 3, 3, 3	3, 3, 3, 3, 3	3, 3, 3, 3, 3
		CC_i	0.819	**0.972**	0.940	0.231	0.181
Exp22	Criteria	Weight	CONT$_1$	CONT$_2$	CONT$_3$	CONT$_4$	CONT$_5$
	Benefit	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost	5, 4, 3, 2, 1	3, 3, 3, 3, 2	3, 3, 3, 3, 3	3, 3, 3, 3, 3	3, 3, 3, 3, 3	3, 3, 3, 3, 3
		CC_i	0.904	**0.970**	0.933	0.154	0.096
Exp23	Criteria	Weight	CONT$_1$	CONT$_2$	CONT$_3$	CONT$_4$	CONT$_5$
	Benefit	5, 4, 3, 2, 1	2, 2, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
		CC_i	0.750	**0.829**	0.706	0.041	0.000
Exp24	Criteria	Weight	CONT$_1$	CONT$_2$	CONT$_3$	CONT$_4$	CONT$_5$
	Benefit	5, 4, 3, 2, 1	5, 5, 5, 5, 2	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost	5, 4, 3, 2, 1	3, 3, 3, 3, 3	3, 3, 3, 3, 3	3, 3, 3, 3, 3	3, 3, 3, 3, 3	3, 3, 3, 3, 3
		CC_i	0.879	**0.971**	0.930	0.066	0.000
Exp25	Criteria	Weight	CONT$_1$	CONT$_2$	CONT$_3$	CONT$_4$	CONT$_5$
	Benefit (1)	5, 4, 3, 2, 1	5, 4, 3, 2, 1	4, 5, 3, 2, 1	3, 4, 5, 2, 1	2, 4, 3, 5, 1	1, 4, 3, 2, 5
	Cost (1)	5, 4, 3, 2, 1	5, 4, 3, 2, 1	4, 5, 3, 2, 1	3, 4, 5, 2, 1	2, 4, 3, 5, 1	1, 4, 3, 2, 5
		CC_i	0.409	**0.422**	0.380	0.248	0.196
Exp26	Criteria	Weight	CONT$_1$	CONT$_2$	CONT$_3$	CONT$_4$	CONT$_5$
	Benefit (2)	5, 4, 3, 2, 1	5, 4, 3, 2, 1	4, 5, 3, 2, 1	3, 4, 5, 2, 1	2, 4, 3, 5, 1	1, 4, 3, 2, 5
	Cost (1)	5, 4, 3, 2, 1	5, 4, 3, 2, 1	4, 5, 3, 2, 1	3, 4, 5, 2, 1	2, 4, 3, 5, 1	1, 4, 3, 2, 5
		CC_i	0.429	**0.438**	0.407	0.261	0.205
Exp27	Criteria	Weight	CONT$_1$	CONT$_2$	CONT$_3$	CONT$_4$	CONT$_5$
	Benefit (7)	5, 4, 3, 2, 1	5, 4, 3, 2, 1	4, 5, 3, 2, 1	3, 4, 5, 2, 1	2, 4, 3, 5, 1	1, 4, 3, 2, 5
	Cost (1)	5, 4, 3, 2, 1	5, 4, 3, 2, 1	4, 5, 3, 2, 1	3, 4, 5, 2, 1	2, 4, 3, 5, 1	1, 4, 3, 2, 5
		CC_i	0.456	**0.460**	0.444	0.279	0.216
Exp28	Criteria	Weight	CONT$_1$	CONT$_2$	CONT$_3$	CONT$_4$	CONT$_5$
	Benefit (1)	5, 4, 3, 2, 1	5, 4, 3, 2, 1	4, 5, 3, 2, 1	3, 4, 5, 2, 1	2, 4, 3, 5, 1	1, 4, 3, 2, 5
	Cost (2)	5, 4, 3, 2, 1	5, 4, 3, 2, 1	4, 5, 3, 2, 1	3, 4, 5, 2, 1	2, 4, 3, 5, 1	1, 4, 3, 2, 5
		CC_i	0.391	**0.407**	0.354	0.235	0.188
Exp29	Criteria	Weight	CONT$_1$	CONT$_2$	CONT$_3$	CONT$_4$	CONT$_5$
	Benefit (1)	5, 4, 3, 2, 1	5, 4, 3, 2, 1	4, 5, 3, 2, 1	3, 4, 5, 2, 1	2, 4, 3, 5, 1	1, 4, 3, 2, 5
	Cost (7)	5, 4, 3, 2, 1	5, 4, 3, 2, 1	4, 5, 3, 2, 1	3, 4, 5, 2, 1	2, 4, 3, 5, 1	1, 4, 3, 2, 5
		CC_i	0.369	**0.391**	0.324	0.220	0.178
Exp30	Criteria	Weight	CONT$_1$	CONT$_2$	CONT$_3$	CONT$_4$	CONT$_5$
	Benefit (9)	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost (1)	5, 4, 3, 2, 1	3, 3, 3, 3, 3	3, 3, 3, 3, 3	4, 4, 4, 4, 4	4, 4, 4, 4, 4	4, 4, 4, 4, 4
		CC_i	**0.960**	0.928	0.929	0.103	0.040
Exp31	Criteria	Weight	CONT$_1$	CONT$_2$	CONT$_3$	CONT$_4$	CONT$_5$
	Benefit (9)	5, 4, 3, 2, 1	5, 5, 5, 5, 5	4, 4, 4, 4, 4	3, 3, 3, 3, 3	2, 2, 2, 2, 2	1, 1, 1, 1, 1
	Cost (1)	5, 4, 3, 2, 1	2, 2, 2, 2, 2	2, 2, 2, 2, 2	3, 3, 3, 3, 3	2, 2, 2, 2, 2	2, 2, 2, 2, 2
		CC_i	0.917	0.887	**0.932**	0.061	0.000

Criteria Weights: 1:ML; 2:MD; 3:MH; 4:HI; 5:VH. Benefit Scores: 1:EBE; 2:BE; 3:WE; 4:AE; 5:EAE. Cost Scores: 1:EAE; 2:AE; 3:WE; 4:BE; 5:EBE.

Exp1, Exp2 and Exp3, test the impact of varying the weights of the criteria on the final decision in the presence of an "ideal" contractor ($CONT_1$). A contractor is considered "ideal" if they scored "5: EAE" in all benefit criteria, and they scored "5: EBE" in all cost criteria. The "ideal" contractor will indubitably win the contract regardless to how other inferior contractors perform and regardless to the weights of the benefit and cost criteria, as shown in Exp1, Exp2 and Exp3. This is due to that the ideal alternative has scores equal to that of the FPIS and 100% far from the FNIS. The former is also true when an "obvious best" contractor ($CONT_1$) is present, as in experiments Exp4 through Exp7. A contractor is considered "obvious best" when no other contractor scores better than them (the obvious best) in any of the criteria. Subsequent experiments; Exp8 – Exp23, illustrate scenarios where no "ideal" or "obvious best" alternative is present.

Since it is common that quality comes at a higher price. One example in building construction is that high quality finishes require costly materials which adds to the total price of the project. Exp8 tests the scenario where high benefits comes at high costs. In this scenario, benefits are considered proportional to costs in general. That is, the more benefits a contractor presents, the more the costs they inquire from the project owners. To illustrate, a contractor coming with high experience, strong financial standing, high technical and human capabilities, and strong management qualities is expected to pose a higher price and require additional time to finish. As illustrated in Exp8, $CONT_3$ came on top although they are not the best in benefits nor they are the contractor with least costs. This presents the chance to contractors, who are not superior in benefits, to maybe invest in costs to win the project. Experiments Exp9 and Exp10 show that it is enough for $CONT_2$ to be one count better in costs than $CONT_1$, who is superior in benefits, to win the contract given no other contractors are superior in costs. The same argument is true for $CONT_3$, as illustrated in Exp11 and Exp12, while it did not help $CONT_4$ and $CONT_5$ although they were ideal in costs as shown in Exp13 and Exp14 respectively.

To build on the common conclusion of experiments Exp9 through Exp12, various scenarios, Exp15 through Exp20, are tested to investigate the impact of investing in one cost criterion on the odds of winning the contract for $CONT_3$. Recall that the weights of cost criteria are such that $C_1 \geq C_2 \geq \ldots \geq C_5$, results from Exp15, Exp16 and Exp17 show that it is enough for $CONT_3$ to be a count ahead in criterion C_1, C_2 or C_3, respectively, to win the contract. Notice that in the three experiments, Exp15, Exp16 and Exp17, $CONT_3$ was inferior in all other cost criteria. On the other hand, Exp18 shows that largely investing in the less important criterion C_4, and ultimately C_5, alone did not win $CONT_3$ the project. Therefore, $CONT_3$ had to invest substantially on both criteria, C_4 and C_5, concurrently to win the contract as illustrated in Exp19 and Exp20. Consequently, experiments Exp21 and Exp22 illustrate two scenarios in which $CONT_1$ fails to win the contract because they came inferior in only one cost criteria while they scored similar to other contractors in the rest of criteria. This conclusion was true for all cost criteria C_1 (Exp21) through C_5 (Exp22).

Exp23 shows the scenario where $CONT_1$ fails to win the contract as a result of highly losing their edge in the two most important benefit criteria simultaneously. The same cannot be generalized for other pairs of benefit criteria. Moreover, the same cannot be concluded if $CONT_1$ sharply degraded in only one criterion even if it is B_1. It is obvious that if other contractors invested more in the most important benefit criteria, they are more likely to win the contract. Exp24 shows another scenario where $CONT_1$loses the contract although they performed as good in cost criteria while they lost their edge in the least important benefit criterion, B_5.

Experiments Exp25 through Exp31 illustrate the impact of various benefit-to-cost relative importance. For example, benefit criteria are set equal in importance to cost criteria in Exp25, and are set two-times more important than cost criteria in Exp26. Contractors are set with mixed scores such that each contractor excels in one benefit and one cost criterion as shown in the experiments. Results obtained from Exp25 through Exp29show that the winning contractor did not change. To verify the results with more homogeneous experiments, experiments Exp11and Exp12 are repeated with a benefit-to-cost such that benefit criteria are nine-times more important than cost criteria, see Exp30 and Exp31 respectively. In Exp30, the winning contractor changed as a result of the narrow gap between the contractors' cost scores. Repeating the experiment with lower benefit-to-cost relative importance showed that the winning contractor does not change when benefit criteria are five-times or less more important than cost criteria. One the other hand, Exp31 show that although the winning contractor in Exp12, $CONT_3$, is also one level ahead in costs, the result did not favor any other contractor due to the large gap between the scores.

Assuming minimum bias among decision makers in addition to the existence of preset expectations, the disagreement among decision makers is expected not to exceed one level of score. For example, one decision maker may argue that a contractor has a quality above expectation (AE) while another deemed it extremely above expectation (EAE), and this will result in a joint evaluation between the two scores. On the other hand, decision makers may have a wider disagreement on the degree of importance of decision criteria. For example, a decision maker may largely focus on the price of the project as the most important cost criterion while another decision makers tresses more on the time of completion. Experiments Exp32 through Exp36, shown in Table 4,illustratescenarios of uncontrolled disagreements among decision makers on both weights of criteria and scores of contractors. Although disagreed, the presence of the "obvious best" alternative results in qualifying $CONT_1$ as expected in Exp32. In Exp33 through Exp36, results illustrate the same evaluation of weights of criteria and scores of contractors. The experiments differ in the relative weight of benefit-to-cost criteria: Exp33 (1:1), Exp34 (3:1), Exp35 (5:1), and Exp36 (1:3), where (3:1), for example, indicates that benefit criteria are three times more important than cost criteria. As a result, the qualified contractor differs from one experiment to another. This illustrates the large impact of the weights of criteria on the results of the tender.

Table 4. The CC_i for contractors for Exp32 – Exp36

	TFN																	
Exp32	Criteria			CONT$_1$			CONT$_2$			CONT$_3$			CONT$_4$			CONT$_5$		
Criteria	WL	WM	WH	SL	SM	SH	SL	SM	SH	SL	SM	SH	SL	SM	SH	SL	SM	SH
B1	8.3	8.8	9.3	9.5	9.8	10	9.5	9.7	10	9	9.2	10	1	4.8	10	1	1.4	2
B2	7.9	8.4	8.9	9.5	9.8	10	9.5	9.7	10	9	9.2	10	1	4.8	10	1	1.4	2
B3	7.3	7.8	8.3	9.5	9.8	10	9.5	9.7	10	9	9.2	10	1	4.8	10	1	1.4	2
B4	6.2	6.7	7.2	9.5	9.8	10	9.5	9.7	10	9	9.2	10	1	4.8	10	1	1.4	2
B5	4.9	5.4	5.9	9.5	9.8	10	9.5	9.7	10	9	9.2	10	1	4.8	10	1	1.4	2
C1	8.3	8.8	9.3	1	1.4	2	1	1.6	2	2	2	2	8.5	6.2	3	9.5	9.6	9.5
C2	7.7	8.2	8.7	1	1.4	2	1	1.6	2	2	2	2	8.5	6.2	3	9.5	9.6	9.5
C3	7.4	7.9	8.4	1	1.4	2	1	1.6	2	2	2	2	8.5	6.2	3	9.5	9.6	9.5
C4	6.7	7.2	7.7	1	1.4	2	1	1.6	2	2	2	2	8.5	6.2	3	9.5	9.6	9.5
C5	4.9	5.4	5.9	1	1.4	2	1	1.6	2	2	2	2	8.5	6.2	3	9.5	9.6	9.5
			CC_i		**1.000**			0.963			0.759			0.358			0.000	
Exp33	Criteria			CONT$_1$			CONT$_2$			CONT$_3$			CONT$_4$			CONT$_5$		
Criteria	WL	WM	WH	SL	SM	SH	SL	SM	SH	SL	SM	SH	SL	SM	SH	SL	SM	SH
B1	8	8.5	9	9	9.6	10	1	8	10	1	7.7	10	1	8	10	1	6.5	10
B2	7.9	8.4	8.9	9	9.4	10	9	9.4	10	9	9.4	10	1	7.7	10	1	7.9	10
B3	7.3	7.8	8.3	1	6.5	10	9	9.6	10	1	6.5	10	9	9.4	10	1	8	10
B4	6.4	6.9	7.4	1	7.9	10	1	7.9	10	1	8	10	9	9.4	10	9	9.6	10
B5	4.9	5.4	5.9	1	8	10	1	8	10	9	9.6	10	9	9.6	10	1	8.2	10
C1	9	9.5	10	2	1.6	2	2	1.8	2	8.5	3.4	2	2	1.8	2	2	1.6	2
C2	9	9.5	10	8.5	3	2	2	1.6	2	2	1.8	2	8.5	3.2	2	8.5	3.2	2
C3	5.9	6.4	6.9	8.5	3.2	2	8.5	3.2	2	8.5	4.6	2	8.5	3.2	2	8.5	3.4	2
C4	4.6	5.1	5.6	8.5	3.4	2	8.5	3.4	2	8.5	3.2	2	8.5	3.2	2	2	1.8	2
C5	4.4	4.9	5.4	2	1.8	2	8.5	3.2	2	8.5	3	2	8.5	3.2	2	2	1.8	2
			CC_i		0.528			**0.586**			0.321			0.479			0.474	
Exp34	Criteria			CONT$_1$			CONT$_2$			CONT$_3$			CONT$_4$			CONT$_5$		
Criteria	WL	WM	WH	SL	SM	SH	SL	SM	SH	SL	SM	SH	SL	SM	SH	SL	SM	SH
B1	6	6.375	6.75	9	9.6	10	1	8	10	1	7.7	10	1	8	10	1	6.5	10
B2	5.925	6.3	6.675	9	9.4	10	9	9.4	10	9	9.4	10	1	7.7	10	1	7.9	10
B3	5.475	5.85	6.225	1	6.5	10	9	9.6	10	1	6.5	10	9	9.4	10	1	8	10
B4	4.8	5.175	5.55	1	7.9	10	1	7.9	10	1	8	10	9	9.4	10	9	9.6	10
B5	3.675	4.05	4.425	1	8	10	1	8	10	9	9.6	10	9	9.6	10	1	8.2	10
C1	2.25	2.375	2.5	2	1.6	2	2	1.8	2	8.5	3.4	2	2	1.8	2	2	1.6	2
C2	2.25	2.375	2.5	8.5	3	2	2	1.6	2	2	1.8	2	8.5	3.2	2	8.5	3.2	2
C3	1.475	1.6	1.725	8.5	3.2	2	8.5	3.2	2	8.5	4.6	2	8.5	3.2	2	8.5	3.4	2
C4	1.15	1.275	1.4	8.5	3.4	2	8.5	3.4	2	8.5	3.2	2	8.5	3.2	2	2	1.8	2
C5	1.1	1.225	1.35	2	1.8	2	8.5	3.2	2	8.5	3	2	8.5	3.2	2	2	1.8	2
			CC_i		0.497			**0.531**			0.354			0.517			0.353	
Exp35	Criteria			CONT$_1$			CONT$_2$			CONT$_3$			CONT$_4$			CONT$_5$		
	W1	W2	W3	SL	SM	SH	SL	SM	SH	SL	SM	SH	SL	SM	SH	SL	SM	SH
B1	6.667	7.083	7.500	9	9.6	10	1	8	10	1	7.7	10	1	8	10	1	6.5	10
B2	6.583	7.000	7.417	9	9.4	10	9	9.4	10	9	9.4	10	1	7.7	10	1	7.9	10
B3	6.083	6.500	6.917	1	6.5	10	9	9.6	10	1	6.5	10	9	9.4	10	1	8	10
B4	5.333	5.750	6.167	1	7.9	10	1	7.9	10	1	8	10	9	9.4	10	9	9.6	10
B5	4.083	4.500	4.917	1	8	10	1	8	10	9	9.6	10	9	9.6	10	1	8.2	10
C1	1.500	1.583	1.667	2	1.6	2	2	1.8	2	8.5	3.4	2	2	1.8	2	2	1.6	2
C2	1.500	1.583	1.667	8.5	3	2	2	1.6	2	2	1.8	2	8.5	3.2	2	8.5	3.2	2
C3	0.983	1.067	1.150	8.5	3.2	2	8.5	3.2	2	8.5	4.6	2	8.5	3.2	2	8.5	3.4	2
C4	0.767	0.850	0.933	8.5	3.4	2	8.5	3.4	2	8.5	3.2	2	8.5	3.2	2	2	1.8	2
C5	0.733	0.817	0.900	2	1.8	2	8.5	3.2	2	8.5	3	2	8.5	3.2	2	2	1.8	2
			CC_i		0.486			0.511			0.365			**0.530**			0.311	
Exp36	Criteria			CONT$_1$			CONT$_2$			CONT$_3$			CONT$_4$			CONT$_5$		
	W1	W2	W3	SL	SM	SH	SL	SM	SH	SL	SM	SH	SL	SM	SH	SL	SM	SH
B1	2	2.125	2.25	9	9.6	10	1	8	10	1	7.7	10	1	8	10	1	6.5	10
B2	1.975	2.1	2.225	9	9.4	10	9	9.4	10	9	9.4	10	1	7.7	10	1	7.9	10
B3	1.825	1.95	2.075	1	6.5	10	9	9.6	10	1	6.5	10	9	9.4	10	1	8	10
B4	1.6	1.725	1.85	1	7.9	10	1	7.9	10	1	8	10	9	9.4	10	9	9.6	10
B5	1.225	1.35	1.475	1	8	10	1	8	10	9	9.6	10	9	9.6	10	1	8.2	10
C1	6.75	7.125	7.5	2	1.6	2	2	1.8	2	8.5	3.4	2	2	1.8	2	2	1.6	2
C2	6.75	7.125	7.5	8.5	3	2	2	1.6	2	2	1.8	2	8.5	3.2	2	8.5	3.2	2
C3	4.425	4.8	5.175	8.5	3.2	2	8.5	3.2	2	8.5	4.6	2	8.5	3.2	2	8.5	3.4	2
C4	3.45	3.825	4.2	8.5	3.4	2	8.5	3.4	2	8.5	3.2	2	8.5	3.2	2	2	1.8	2
C5	3.3	3.675	4.05	2	1.8	2	8.5	3.2	2	8.5	3	2	8.5	3.2	2	2	1.8	2
			CC_i		0.557			**0.636**			0.291			0.444			0.586	

Due to the lack of a detailed case study in the literature, the proposed model was not inspected against published results from the literature. Most published case studies use different scales and are not governed by the expectations of the project stakeholders. On the other hand, the model proposed in this study can be adapted by future researchers for comparison purposes. Investigators can mold their MCDM problem to adapt to the model, and they can compare attained results under the different scenarios that better address the dynamics of their case study.

5. Conclusion

This study used a five-point scale Fuzzy-TOPSIS technique to demonstrate the impact of uncertainties in selecting among contractors. The study accounts for benefit and cost criteria with considerable importance to the decision maker. The five-point scale enhances ease of comparison of contractor qualities against predetermined expectations. The used scale avoids overrating contractor’s qualities beyond the expected sufficient levels to successfully complete the project while largely penalizing qualities under the expected levels. Thirty-six scenarios were conducted and the closeness coefficient of five contractors were recorded. The study aimed to demonstrate the impact of various evaluation uncertainties on the likelihood of selecting a contractor for the tender. Utilizing the many results obtained from the study, a contractor may change their odds in winning the tender by understanding their strengths and weaknesses and that of their competitors. Moreover, contractors must understand the degrees of importance of qualifying criteria to project owners. While many focus on project price and completion time, some researchers reported that project owners highly considered safety practices of contractors over other criteria.

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