Turkish Journal of Civil Engineering, 2023 153-165, Paper 721, ***Technical Note***

Solution Proposals based on Fuzzy AHP-TOPSIS Hybrid Model to the Problems in Public Works Procurement in Turkey

İbrahim ÖZYÜREK[1]
Mürsel ERDAL[2]

ABSTRACT

In the transition from price-based tender evaluation to multi-criteria bid evaluation process in public procurements pioneered by academic research, the aim is to ensure the delivery of the project at the desired quality without exceeding the time and budget of the contract process. In the tenders implemented according to the Public Procurement Law (PPL), while the lowest price principle was used in the bid evaluation stage, non-price elements began to be used in time. However, complexity in regulations brought about longer tender evaluation process and more conflicts. In this study, solutions to current problems such as the evaluation of abnormally low in the tenders made within the scope of the law, the long duration of the bid evaluation process, and the high number of conflicts are proposed through the model created by Fuzzy AHP-TOPSIS methods.

Keywords: Tender, MCDM, TOPSIS, contractor selection.

1. INTRODUCTION

In Turkish public procurement practice, most frequently used procedure for selecting contractors has been open tendering and mostly tenderer who offered the lowest price was awarded the contract. This made tenderers to consider the price down in tender and retrieve profits during implementation of projects benefiting from ambiguities in the documents and weakness of supervision. The price to quality evaluation has resulted in so many unfavorable results such as unfinished projects due to contractor's inability to complete project, high maintenance costs due to poor quality of structure, and environmental damage due to contractor's failure to take necessary costly measures to respect the environment. Consequently, a gradual shift from lowest price to most economically advantageous tender evaluation took place. Most economically advantageous tender involves monetary and non-

Note:
- This paper was received on December 20, 22021 and accepted for publication by the Editorial Board on November 11, 2022.
- Discussions on this paper will be accepted by March 31, 2023.
- https://doi.org/10.18400/tjce.1209197

1 Public Procurement Authority, Ankara, Türkiye
iozyurek@hotmail.com - https://orcid.org/ 0000-0002-1141-5135

2 Gazi University, Faculty of Technology, Department of Civil Engineering, Ankara, Türkiye
merdal@gazi.edu.tr - https://orcid.org/ 0000-0002-9338-6162

monetary element, making tender evaluation a multi-criteria decision making (MCDM). These elements exclude the qualification criteria. However, subject of works procurement is not a good with known specifications but a work and delivery process which is directly shaped by qualifications of tenderers. Therefore, it is important that qualifications of tenderers be put into a multi-criteria tender evaluation.

MCDM involves deciding on the best alternative from a set of potential candidates. These alternatives often contain multiple and conflicting criteria that can be qualitative or quantitative [1]. There have been numerous MCDM methods offered by researchers to select the right contractor, such as, the analytical hierarchy process (AHP) [2], ELECTRE [3], multi-attribute utility theory (MAUT) [4], PROMETHEE [5], TOPSIS [6] etc.

In this study, it is aimed that the time required to award the contract be shortened, the tenders be evaluated together with the qualifications of the bidders, the abnormally low tender inquiry and explanation processes be removed, and hence the most suitable contractor be selected in a relatively shorter time.

2. BACKGROUND

Tenderers partaking in the procurement proceedings may submit documents for evaluation of their eligibilities. The qualification documents that have to be submitted in tender are decided by the contracting authorities (CA) according to the estimated cost of the procurement. Tenderers who do not meet the thresholds are disqualified. After this stage, there exists an abnormally low tender identification, explanation, and evaluation process.

To determine abnormally low tenders, PPL uses “limit value” that is calculated using approximate cost and bid prices. However, the limit value carries a risk that it can be manipulated by tenderers. In the prevalence of abnormally low tenders, CA may ask tenderers for explanation about important components of their prices. The methods of explanation are defined in the regulations. In the next stage, CA accept the explanation if it is duly prepared or reject it otherwise.

Following the evaluation mentioned above, CA shall award the contract to the tenderer who submitted most economically advantageous tender. According to PPL article 40, the economically most advantageous tender is determined either solely on the basis of price or on the basis of both price and non-price factors such as operation and maintenance costs, cost effectiveness, productivity, quality, and technical value. Despite both types of evaluation, problems may arise during the delivery of project in conformity with the terms of the contract. Therefore, the public might not benefit from the project of interest as desired. Also, during the implementation of the project, adversarial relationship between the CA and the contractor may arise due to contractor’s inabilities and low contract price from contractor’s point.

Another pitfall of the existing procedure is that it allows tenderers offering prices under limit value to refrain from signing contract because there is no sanction in regulations to those who do not submit their explanation or submit unduly prepared explanation. This creates a region of agreement between tenderers which increases contract value. To make it clear, let’s see Table 1. In the table, Tenderers A, B and C, whose prices are abnormally low, could be awarded the contract, however, most probably due to an agreement, they do not submit explanation and contract value increase from 133 to 149.

Table 1 - A sample list of bid prices in a tender

Tenderer	*Bid Price*	*Action*
A	133	No explanation submitted – Reject tender
B	135	No explanation submitted – Reject tender
C	140	No explanation submitted – Reject tender
D	149	Explanation accepted – Award contract
Limit Value	150	Components of tenders below this value must submit explanation
E	153	Valid tender
F	165	Valid tender

The tender evaluation procedure currently applied in Turkey and the offered change in this process are shown in Figure 1.

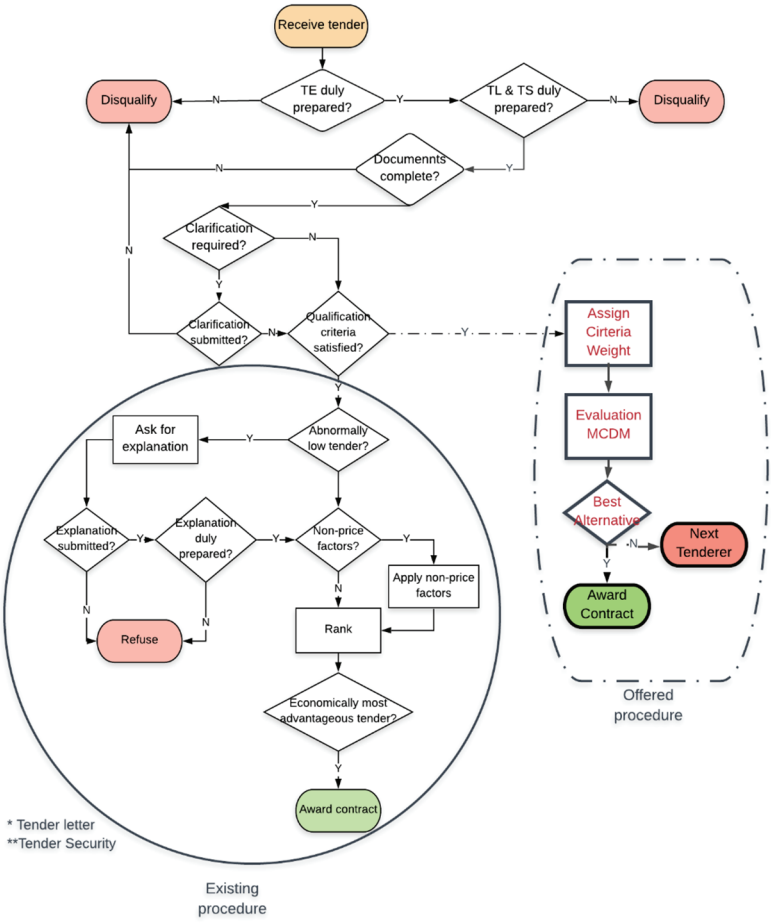

Figure 1 - Tender Evaluation Process in Public Procurement Law and offered modification

The study proposes a model to be applied in the tenders implemented by open tender procedure and negotiating procedure. The qualification criteria to be used are limited to the criteria detailed in the Construction Works Tenders Implementing Regulation.

3. METHODOLOGY

The most important advantage of multi-criteria methods is their capability to weigh conflicting interests during selection. The AHP is a technique that can be easily combined with other methods, and TOPSIS is a method that is algorithmically structured and easy to compute, especially when acting in combination with other techniques [7]

The proposed model is a fuzzy AHP-TOPSIS hybrid model, which obtains criterion weight through fuzzy AHP and ranks alternatives by TOPSIS.

This model consists of

(a) a number of tenderers, denoted as T_i *…i=1; 2; . . . ; n*;

(b) a set of evaluation criteria consisting of qualification criteria and tender price *Cj …j=1, 2, . . . ,m,*

(c) tenderers' qualifications and tender prices x_{ij} *…i=1, 2, . . . , n; j=1, 2, . . . ,m;*

(d) a weight vector $w = \ldots w_1, w_2, \ldots, w_m$ (referred to as criteria weights) representing the relative importance of the evaluation criteria with respect to the contractor selection.

In order to determine the weight of these criteria in the evaluation of tenders, a questionnaire consisting of paired comparisons about the criteria was conducted. Then, 18 different scenarios were formed according to the qualification criteria that tenderers must meet in the tenders and by using the survey results, the weights for each criterion in each scenario were determined by Fuzzy AHP methods [8]. The weights obtained, were then transferred to Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method. In TOPSIS applications, 15 different applications were proposed. These methods were aimed at i) mitigating with abnormally low tenders, ie. tenders below limit value, ii) mitigating with tenders above approximate cost when other tenderers have poor quality, iii) mitigating with high tender prices of over-qualified tenderers

The results of these practices were evaluated separately for four different tenders and recommendations were submitted. Only one example will be given here. For other examples readers are refered to [8].

2.1. Criterion Weight, Fuzzy AHP

AHP was selected to assign criteria weights as i) it is one of the most frequently used MCDM methods in construction management literature, ii) it has excellent performance in dealing with both tangible and intangible criteria, iii) reliability can be controlled with consistency ratio, iv) experts get better understanding about study objectives with a hierarchical representation and v) it provides easy implementation [9]

Since there were large deviations in evaluations by decision-makers, fuzzy numbers should be used. In FAHP, the pair wise comparisons of criteria were performed through the linguistic variables, which are represented by triangular numbers. The fundamental scale is transformed into triangular fuzzy numbers as in Table 4.

Table 4 - The fundamental scale used in the study

Intensity of Importance	Definition	Fuzzy Triangular Scale
1	Equal importance	(1,1,1)
3	Weak importance of one over another	(2,3,4)
5	Essential or strong importance	(4,5,6)
7	Demonstrated importance	(6,7,8)
9	Absolute importance	(9,9,9)
2	The intermittent values between two adjacent scales	(1,2,3)
4		(3,4,5)
6		(5,6,7)
8		(7,8,9)
Reciprocals of above nonzero	If activity *i* has one of the above nonzero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value in reverse order when compared with *i, ie. ij=(2,3,4) then ji=(1/4,1/3,1/2)*	

Table 5 - Criterion weights suggested by Ozyurek [8]

Case	Bank Reference Letter (BRL)	Current Ratio (CR)	Equity Ratio (ER)	Short Term B. Loans / Euqity	Annual Turnover (AT)	Work Experience (WE)	Quality Certificate (QC)	Environment Certificate (EnC)	Tender Price (TP)	Estimated Cost (EC)
1	*No*					**26,94**	*No*		**73,06**	0-0,1 Threshold Value (TV)
2						19,36			73,06	
3	**---**	1,52	2,15	2,07	5,36	25,06			63,85	0,1TV-0,5TV
4	**0,95**	**1,40**	**1,98**	**1,91**	**4,87**	**25,06**			**63,85**	
7	**---**	1,52	2,15	2,07	5,36	20,82	4,24	**---**	63,85	> 0,5 TV
8	0,95	1,40	1,98	1,91	4,87	20,82	4,24	**---**	63,85	
9	**---**	1,52	2,15	2,07	5,36	21,00	**---**	4,06	63,85	
10	0,95	1,40	1,98	1,91	4,87	21,00	**---**	4,06	63,85	
15	**---**	1,52	2,15	2,07	5,36	17,89	3,97	3,20	63,85	
16	0,95	1,40	1,98	1,91	4,87	17,89	3,97	3,20	63,85	

Ozyurek [8] suggested the following weights for qualification criteria through processing by FAHP the outcomes of the survey among public procurement specialists at Public Procurement Authority. For details of the survey, see Ozyurek [8][10].

2.2. Ranking of Alternatives: Technique for Order Preference by Similarity to An Ideal Solution

Technique for Order Preference by Similarity to an ideal solution (TOPSIS) was introduced by Hwang and Yoon [11]. In TOPSIS method, positive ideal solution maximizes benefit criteria and minimizes cost criteria. Negative ideal solution maximizes cost criteria and minimizes benefit criteria [12]. Hence, alternatives should have shortest distance from positive ideal solution and farthest from negative ideal solution

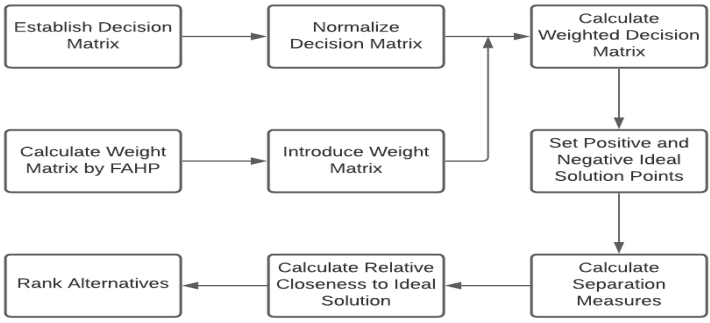

Figure 4 - TOPSIS Method

For alternatives 1 and 2 shown in Figure 5, it is seen that Alternative 2 is farther away from the negative ideal solution point and closer to the positive ideal solution point, so Alternative 2 is more similar to the ideal solution.

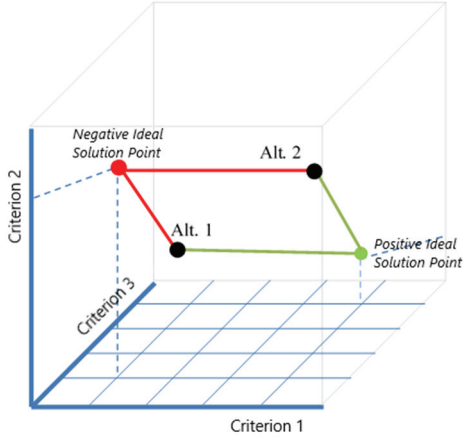

Figure 5 - Ranking of alternatives in TOPSIS

In applications where TOPSIS method is employed, it is a general approach that positive and negative ideal solutions are selected as either maximum or minimum points in each criterion. However, due to the nature of tender evaluation system, assigning max or min points as ideal solutions sometimes do not help us select the right contractor to deliver the project in desired conditions and price. It is worth to remind here that we are restricted with the qualification criteria in PPL. Therefore, within the frame of qualification criteria, some suggestions are made to select contractor to deliver project timely, safely and within the desired quality. Mostly encountered problems and suggestions are given in the next part.

4. APPLICATIONS and DISCUSSION

Scenario 1: Abnormally low tenders

The projects delivered by contractors who offered abnormally low price are generally defective and operation and maintenance costs are high. It is desired that tenderer, who offered abnormally low price compared to the other prices and/or the estimated cost determined by the CA, stop gaining price advantage beyond an appreciable value.

Solution:

In the scenario, limit value which is determined by a formula defined by Public Procurement Authority was selected as the positive ideal solution point. This reduces the price advantage of the tenderers below limit value. The lower the price beyond limit value the further it gets away from the positive ideal solution. On the other hand, it still continues to get further away from the negative ideal solution.

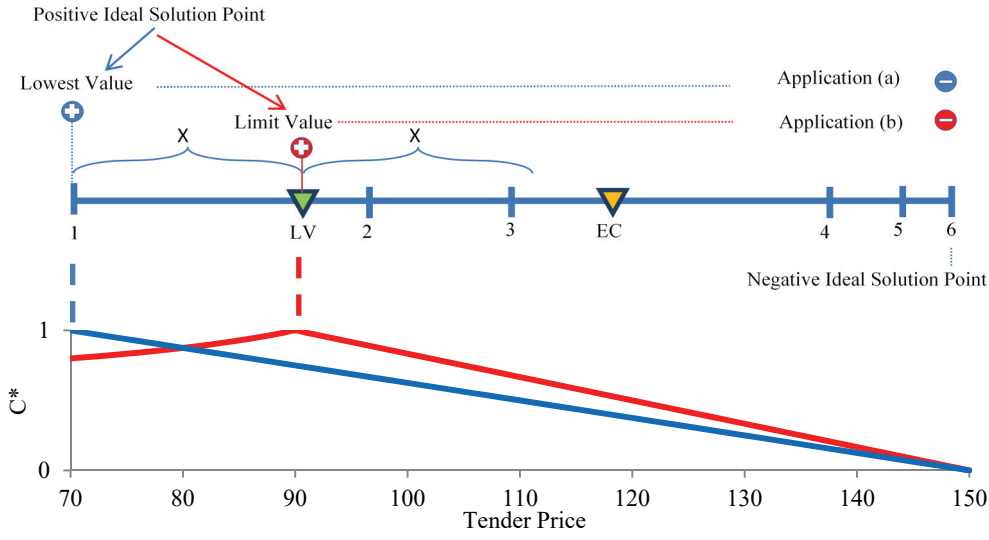

Figure 6 - Selection of positive ideal solution point for abnormally low tender evaluation

Figure 6 shows the effect of assigning limit value to positive ideal solution point. In application (a), for price criterion, the distance of Tenderer 1 to the positive ideal solution is zero while in application (b) it is (X). This makes the tenderer with low qualifications hesitate to offer abnormally low prices. In the former case, as the price goes from maximum to minimum price, the value of C in price criterion increases linearly and reaches at 1 at the minimum price while in the latter case; it reaches at 1 at the limit value and drops parabolically after then. This is the case when only the price criterion is considered that is w_{TP}=1,00.

Scenario 2 Over-qualification Problem

This problem is not the case for procurement process already in use. However, it will be a problem when tenderers' qualifications are put into evaluation in a multi criteria decision making. Tenderers with high qualifications would tend to offer higher prices to make higher profits and they would be awarded the contract, resulting in cost overrun for CA unless limits are applied for the qualification values. The aim of the tender evaluation model proposed hereby is to select the most suitable contractor who can deliver the project in time and budget and desired quality. Thus, CA should not pay for the quality beyond its necessity.

Solution: Qualification criteria should be evaluated by considering the size of the work subject to the tender. The excessive amount should not be taken into consideration for qualification criteria beyond the size comparable to the subject of the contract. Therefore, apply cut-off values to the qualification criteria so that unnecessary payment by the CA to the excessive qualification is prevented. The cut-off values can be determined by tender price or estimated cost as shown in Figure 7. In this application tender price is used. For qualification criteria, independent of tender price, the market conditions should be taken into account.

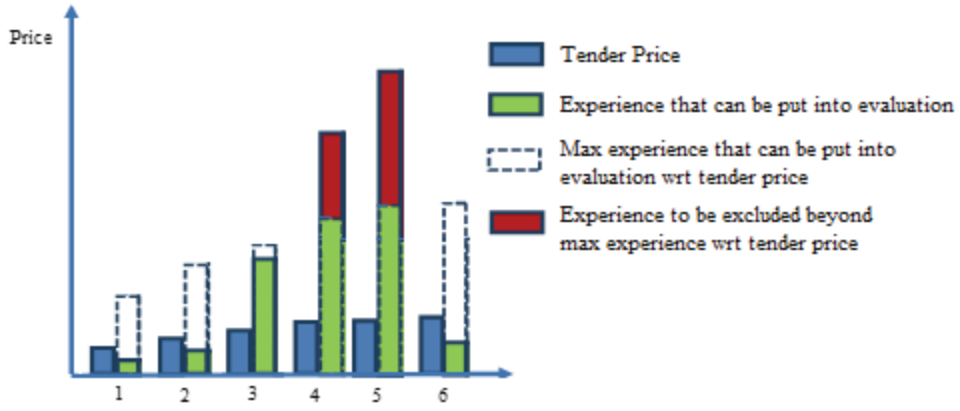

Figure 7 - Solution to over-qualification problem

Scenario 3: Promoting Successful Project Management

In this application, dimensionless numbers are assigned. The point here is that companies that have better management capacity can complete projects at lower costs so they should not

be deprived of monetary qualification criteria since the same project if completed by a company with improper management capacity can cost much higher values. Let's consider a hospital tender that is made according to PPL. Also, assume that tender prices are 12, 12.5, 14, 15 and 16 million Turkish Liras, only-price based selection is applied, and all tenderers are eligible. If tenderer 1 is awarded the contract it will get 12 million work experience while if tenderer 3 is awarded, then it will get 14 million work experience. This unfair advantage can be levelled by using a dimensionless work experience parameter. The dimensionless parameter in this application is obtained by dividing work experience value by tender price as shown in Figure 8.

$$WE^* = \frac{\mathrm{WE}}{\mathrm{EC}}$$

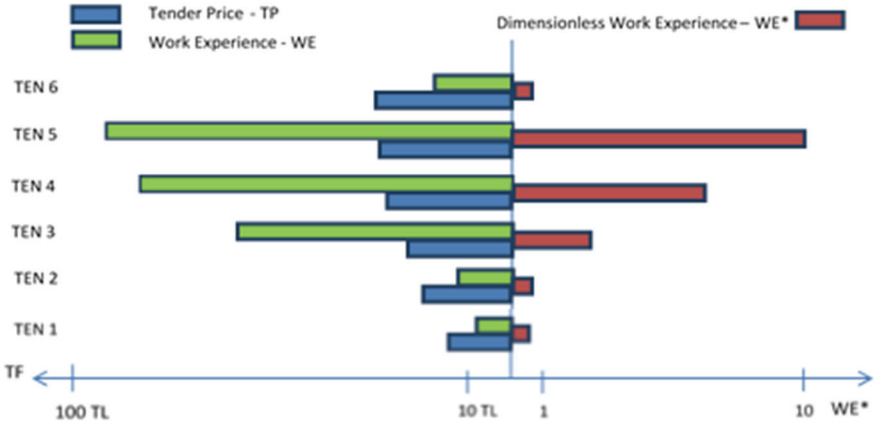

Figure 8 - Dimensionless parameters

Scenario 4: Preventing Contracts above estimated cost

Some tenders result in a contract price above the approximate cost. This is due to the lack of competitive environment, agreement between the tenderers, illegal relations between the tender authority and the tenderers and some similar situations. To prevent this, it is necessary to collect the prices higher than the estimated cost at the negative ideal solution point. In public procurement, with the effect of competition, the contract price is generally less than the estimated cost even limit value. However, in some cases, contracts above estimated costs are signed. Secondary regulations also allow this conduct. From this point of view, determining the highest bid price as the negative ideal solution point and accepting the distance of prices above estimated cost to the negative ideal solution point as zero, as shown in Figure 9, is an appropriate solution to prevent the procurement to be placed at a price above the estimated cost for the subject of the tender.

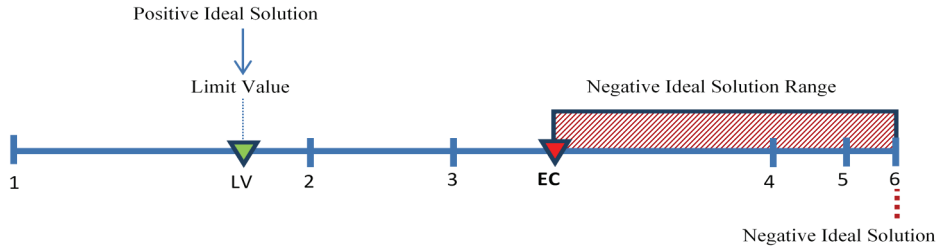

Figure 9 - Negative ideal solution to prevent contracts above estimated cost

Example

The estimated cost of the tender for a pond construction work is 7 614,15 TL. Eight tenderers participated in the tender, two tenderers were excluded from evaluation process for various reasons and the limit value was calculated as 5 901,75 TL. Tenderer with 4 400,00 TL bid price was awarded the contract. Only the work experience certificate was requested as the qualification criterion in this tender.

This tender is the tender with the minimum number of qualification criteria required. In this case, the decision tree has two branches and the weights 26,94 % for work experience and 73,06 % for tender price [8].

Table 6 - Qualifications and tender prices in Tender 1

"	Tenderer 1	Limit Value	Tenderer 2	Tenderer 3	Estimated Cost	Tenderer 4	Tenderer 5	Tenderer 6
Work Experience	2 531,46	5 901,75	3 911,15	19 464,00	7 614,15	57 719,63	93 239,57	2 531,46
Tender Price	4 400,00		6 224,36	7 372,65		8 840,67	9 313,00	9 563,00

Table 7 - Results of application (a)

Tenderer	WE	TF	C_i^*	*Rank*
Tenderer 1	2 531,46	4 400,00	0,4729	2
Tenderer 2	3 911,15	6 224,36	0,3594	4
Tenderer 3	19 464,00	7 372,65	0,3055	5
Tenderer 4	57 719,63	8 840,67	0,4179	3
Tenderer 5	93 239,57	9 313,00	0,5397	1
Tenderer 6	5 532,33	9 563,00	0,0245	6

The aforementioned four solutions were applied, and the results are as follows.

a) In application (a), the qualification values of tenderers were directly applied. Although, the tender price by Tenderer 5 was very high, it was awarded the contract since it had

comparatively higher work experience value. This is the expected result of a multi-criteria decision-making application, however in public procurement applications it must be avoided. A solution to this problem will be offered in application (c).

b) In this application, a solution to evaluation of abnormally low tenders is offered. Therefore, below a limit value, which is formulated by PPA, it is assumed that the price is questionable. The solution offered is that select the limit value as the positive ideal solution point in price criterion so that remove the low-price advantage of the abnormally low tenderers. Selecting limit value as positive ideal solution point made Tenderer 4 the economically most advantageous second tenderer since Tenderer 1 lost its price advantage.

Table 8 - Results of application (b)

Tenderer	WE	TF	C_i^*	*Rank*
Tenderer 1	2 531,46	4 400,00	0,4647	3
Tenderer 2	3 911,15	6 224,36	0,3704	4
Tenderer 3	19 464,00	7 372,65	0,3321	5
Tenderer 4	57 719,63	8 840,67	0,4912	2
Tenderer 5	93 239,57	9 313,00	0,6281	1
Tenderer 6	5 532,33	9 563,00	0,0278	6

c) In this application, excessive qualification was cut off. The limit for work experience was decided to be three times tender price. Now, the contract price fell to 7 372,65 TL. Since high qualification advantage turned out to be over qualification problem and Tenderer 5 lost its advantage.

Table 9 - Results of application (c)

Tenderer	WE	TP	C_i^*	*Rank*
Tenderer 1	2 531,46	4 400,00	0,5412	4
Tenderer 2	3 911,15	6 224,36	0,4617	5
Tenderer 3	19 464,00	7 372,65	0,6356	1
Tenderer 4	26 522,01	8 840,67	0,5726	2
Tenderer 5	27 939,00	9 313,00	0,5470	3
Tenderer 6	5 532,33	9 563,00	0,0861	6

d) In application (d), dimensionless work experience took place of work experience in application (c). Dimensionless work experience was limited by 3 and limit value was selected as positive ideal solution point.

Table 10 - Results of application (d)

Tenderer	WE*	BP	C_i^*	*Rank*
Tenderer 1	0,5753	0,5778	0,5835	2
Tenderer 2	0,6284	0,8174	0,5024	4
Tenderer 3	2,6400	0,9682	0,6990	1
Tenderer 4	3,0000	1,1610	0,5394	3
Tenderer 5	3,0000	1,2230	0,4973	5
Tenderer 6	0,5785	1,2559	0,0009	6

e) In the last application, all solutions were applied together. The decreases in C* of tenderers with tender prices above estimated cost (Tenderer 4 and 5) are noteworthy.

Table 11 - Results of application (e)

Tenderer	WE*	BP	C_i^*	*Rank*
Tenderer 1	0,5753	0,58	0,5835	2
Tenderer 2	0,6284	0,82	0,5024	4
Tenderer 3	2,6400	0,97	0,6990	1
Tenderer 4	3,0000	1,16	0,5338	3
Tenderer 5	3,0000	1,22	0,4966	5
Tenderer 6	0,5785	1,26	0,0009	6

5. CONCLUSION

This paper revealed some problems inherited in the present public works procurement processes and offered a multi-criteria evaluation model to overcome these problems in a timely manner. Fuzzy numbers were used in assigning criterion weight since the survey showed large deviations in evaluations by participants. The first step offered was putting tenderers' qualifications into tender evaluation to award the contract. This method of evaluation can assure delivery of project of higher quality. Uncontrolled quality to price evaluation brought about the over-qualification problem which can result in budget overrun. Therefore, this step alone has proved to be insufficient. The over-qualification problem was successfully overcome by putting thresholds to tenderer qualifications preventing CAs from paying for quality beyond their necessities. Another major pitfall of procurement system is evaluation of abnormally low tenders which is an isolated process within tender evaluation process. In the model offered, this time- taking process was successfully replaced by assigning limit value to the positive ideal solution point. This assignment eliminated the price advantage of tenderers beyond the limit value. A rarely occurring phenomenon, however, still important for achieving financial aims is contracting with a tenderer who offered price above approximate cost. Similar to the case of abnormally low tenders but with some difference, approximate cost was assigned to negative ideal solution point providing that relative closeness of such tenders decreased.

References

[1] K. T. Cho, "Multicriteria decision methods: An attempt to evaluate and unify," Mathematical and Computer Modelling, vol. 37, no. 9-10, pp. 1099-1119, 2003.

[2] E. W. L. Cheng and H. Li, "Contractor selection using the analytic network process," Construction Management and Economics, vol. 22, no. 10, pp. 1021-2032, 2004.

[3] M. Marzouk, "An Application of ELECTRE III to Contractor Selection," in Construction Research Congress: Innovation for Reshaping Construction Practice, Banff, Alberta, Canada, 2010.

[4] S. Lambropoulos, "The use of time and cost utility for construction contract award under European Union Legislation," Building and Environment, vol. 42, no. 1, pp. 452-463, 2007.

[5] M. Araújo, L. H. Alencar and C. Mota, "Contractor Selection in Construction Industry: a Multicriteria Model," in 2015 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), Singapore, 2015.

[6] D. Putra and P. Pratama, "Decision support system selection of tender winners project development building of STMIK STIKOM Indonesia with TOPSIS method," Journal of Physics: Conference Series, vol. 1469, pp. 12-26, 2020.

[7] M.-Y. Cheng, S.-H. Yeh and W.-C. Chang, "Multi-Criteria Decision Making of Contractor Selection in Mass Rapid Transit Station Development Using Bayesian Fuzzy Prospect Model," Sustainability, vol. 12, no. 11, p. 4606, 2020.

[8] İ. Özyürek, "An Alternative Method Proposal For Selection Of Contractor In Public Works Procurement," PhD Thesis, Graduate School of Natural and Applied Sciences, Gazi University, Ankara, 2018.

[9] A. P. Gurgun and K. Koc, "Contractor prequalification for green buildings—evidence from Turkey," Engineering, Construction and Architectural Management, vol. 27, no. 6, pp. 1377-1400, 2020.

[10] İ. Özyürek and M. Erdal, "Assessment of Qualification Criteria Described in Public Procurement Law Code 4734 in Construction Works by Analytic Hierarchy Process (AHP)," Gazi University Journal of Science, vol. 31, no. 2, pp. 437-454, 2018.

[11] H. a. Yoon, Multiple Objective Decision Making: Methods and Application, Berlin/Heidelberg/New-York: Springer Verlag, 1981.

[12] M. Amiri-Aref, N. Javadian and M. Kazemi, "A new fuzzy positive and negative ideal solution for fuzzy TOPSIS," WSEAS Transactions on Circuits and Systems, vol. 11, no. 3, pp. 92-103, 2012.