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Analysis of Criteria Influencing Contractor Selection Using TOPSIS Method

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Abstract. Selection of the most suitable contractor is an important process in public construction projects. This process is a major decision which may influence the progress and success of a construction project. Improper selection of contractors may lead to problems such as bad quality of work and delay in project duration. Especially in the construction projects of public buildings, the proper choice of contractor is beneficial to the public institution. Public procurement processes have different characteristics in respect to dissimilarities in political, social and economic features of every country. In Turkey, Turkish Public Procurement Law PPL 4734 is the main regulatory law for the procurement of the public buildings. According to the PPL 4734, public construction administrators have to contract with the lowest bidder who has the minimum requirements according to the criteria in prequalification process. Public administrators are not sufficient for selection of the proper contractor because of the restrictive provisions of the PPL 4734. The lowest bid method does not enable public construction administrators to select the most qualified contractor and they have realised the fact that the selection of a contractor based on lowest bid alone is inadequate and may lead to the failure of the project in terms of time delay Eand poor quality standards. In order to evaluate the overall efficiency of a project, it is necessary to identify selection criteria. This study aims to focus on identify importance of other criteria besides lowest bid criterion in contractor selection process of PPL 4734. In this study, a survey was conducted to staff of Department of Construction Works of Eskisehir Osmangazi University. According to TOPSIS (**T**echnique for **O**rder **P**reference by **S**imilarity to the **I**deal Solution) for analysis results, termination of construction work in previous tenders is the most important criterion of 12 determined criteria. The lowest bid criterion is ranked in rank 5.

1. Introduction

One of the major tasks in construction works is to select proper contractor. Selecting the proper contractor among various applicants to the construction work is directly proportional to the success of the construction project.

The selection of a contractor for the building works is a complicated process and depends on in its major aspect on the correct preparation of the procurement tender specification where all the needs and requirements of the contracting authorities are precisely defined [1]. Selection of the contractor has been primarily on the basis of bid price alone and the lowest tender price is usually described as being the key to winning a contract [2].

Evaluating contractors and selecting the best bidder requires a sophisticated knowledge and experience to ensure that the selected contractor is capable of executing the project according to the owner’s requirements [3]. Owners in different private construction sectors have different procedures for evaluating the tender proposals and they mostly develop their own procedure which is an unrestrictive system for tender evaluation. In public sectors, however, the lowest bid is the main criterion for selecting the contractor [4], because clients are publicly responsible and must demonstrate that the best value for their money has been achieved [5].

The selection of the contractor based on the lowest bid price causes project delivery problems, as contractors quote low prices by reducing their work quality and hope to be compensated by submitting claims [6]. In the present state, public owners in Turkey have to choose the contractor which gives the lowest price according to the rules of Turkish Public Procurement Law PPL 4734. As far as non-price criteria are concerned, there are no clear regulations, standard forms and instructions for contractor evaluation method in PPL 4734 [3].

The aim of this study is to determine the criteria that can be used for evaluation as well as price in the selection of contractors in public projects and to find out the importance of these criteria. The survey prepared for this purpose is conducted to the staff of Department of Construction Works of Eskisehir Osmangazi University. The results obtained from the survey were evaluated by the TOPSIS method which is a multi-criteria decision making method. As a result of the analysis, the lowest price criterion was found as the 5th criterion among 12 criteria.

2. Construction Contractor Selection Process in Turkey

PPL 4734, which entered into force in 2003 and was held in accordance with the directives of State Bidding Law No. 2886, cannot be able to solve the problems in practice. Public construction tenders in Turkey are made according to Article 40 of the Public Procurement Law 4734. Accordingly, the tender remains on the economically most advantageous bidder. Article 67 of the Implementing Regulation for Construction Business Laws, which is organized in parallel with the tender law, considers the most economically advantageous tender as the "lowest price tender", and then, when it is not possible to determine the most economically advantageous tender only on the basis of price and lowest price, the other factors such as cost, cost efficiency, productivity, quality and technical value of tender is considered [7].

As an obligatory law in Turkey, PPL 4734 only allows public authorities to apply traditional project delivery system for procurement of the public buildings. According to the PPL 4734 tender to predetermined bidders process should be used in contractor selection process. This contractor selection process consists of three main phases. Details of the main phases are shown in figure 1.

These phases are as follows [8]:

1) Pre-qualification phase and invitation to bidding,
2) Tender commission process and bidding phase and
3) Invitation to contract and signing of the contract phase.

Contractor selection is a decision-making process that involves the development and consideration of a wide range of necessary and sufficient decision criteria as well as the participation of many decision makers [9]. In practice, it is a multi-criteria decision making problem in which multiple decision makers evaluate the contractor’s attributes according to several criteria.

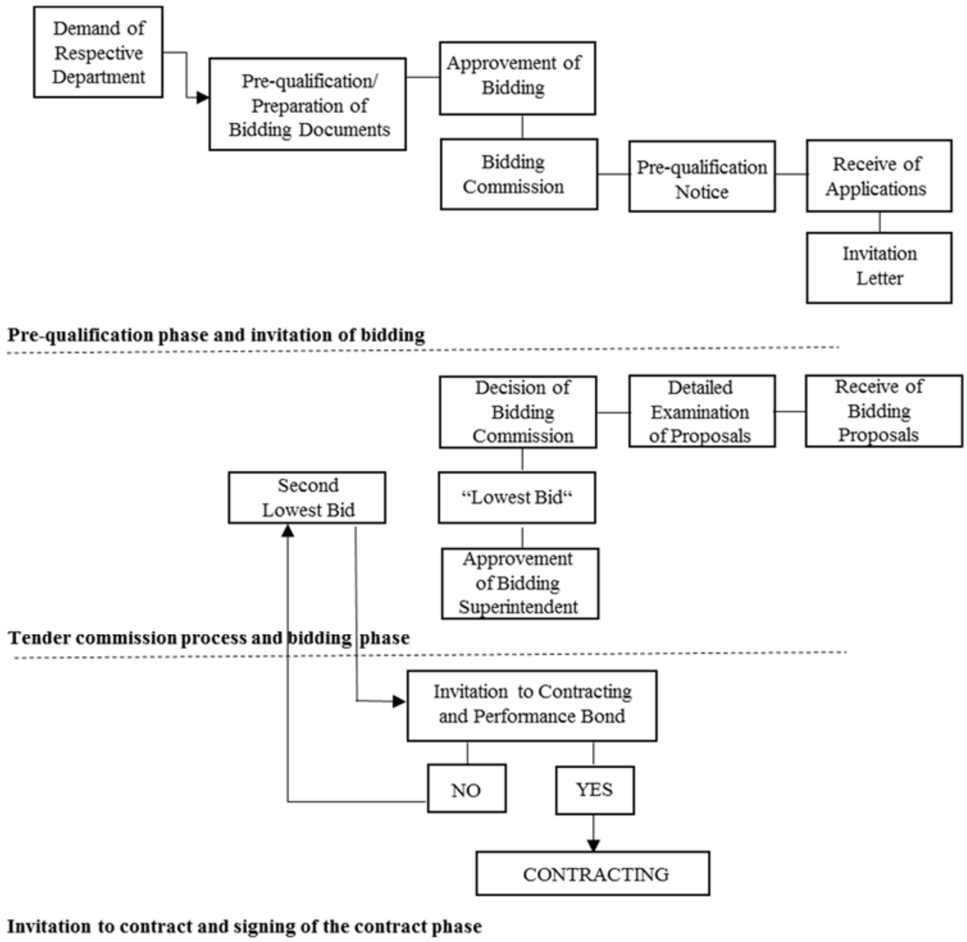

Figure 1. Contractor selection process of Turkish public building procurement

There are some drawbacks to consider only the lowest price criterion in contractor selection process. In order to remove these drawbacks, it is necessary to consider some other criteria besides the lowest price in the selection process. These criteria can be summarized as tender cost, past performance, financial, technical, managerial, quality, and health and safety aspects. Because of the contractor selection has multiple decision makers and multi-criteria, it is a multi-criteria decision making problem. Construction researchers and practitioners have incorporated multi-criteria decision making methods in their models.

Due to its multi-criteria structure, besides the lowest price criterion in the contractor selection problem, it is known that the non-price criteria are extremely effective in decision process. For this purpose, in this study it has been tried to determine the importance of the criteria that are considered to be effective in the decision-making process with the lowest bid. The criteria used in the study are shown in the table 1.

Table 1. Contractor selection criteria

Criteria	Explanation
Financial Credibility	Letter of credit indicating that the amount of tender foreseen is taken as guarantee
Financial Strength	Sufficiency of the financial structure of the construction firm
Materials and Equipment	Sufficiency of technical equipment and materials that the construction firm has
Experience of Technical Staff	Experiences, capabilities and competencies, skills including professional and technical expertise of key construction staff
Number of Technical Staff	Sufficient number of technical personnel to be involved in the project
Safety Plan and Safety Record	Availability of safety measures on site, health and safety information about employees/Safety health record and accident rate
Termination of Construction Work	Whether or not there is a termination in the previous works
Construction Work Quality Reference	Availability of a reference to past public construction works
Work Experience Document	Availability of the document submitted to the Contracting Entity regarding the tender subject business or similar work undertaken under a contract containing a fee
Similar Work Experience	Experience with similar construction projects on past
Lowest Bid	Lowest price offer
Length of time in construction sector	Years of the construction firm in construction sector

3. Methodology

In this section, it is discussed the theoretical background of Entropy and TOPSIS methods. In this paper, Entropy method is used to weight of the survey results given in five scales. Afterwards, TOPSIS method ranked the contractor selection criteria.

3.1. Entropy Method

Entropy is firstly appeared in thermodynamics and was introduced into the information theory later by Shannon [10]. It is general measure of uncertainty in information theory. It is represented by a discreet probability distribution, in which broad distribution represents more uncertainty. When the difference of the value among the evaluating objects on the same indicator is high, while the entropy is small, it illustrates that this indicator provides more useful information, and the relative weight of this indicator would be higher and vice versa. Entropy method is an objective way for weight determination [11]. The calculation of entropy includes the following steps. The first step of entropy is to get the normalized decision matrix $R=\left(r_{ij}\right)_{mxn}$ and $r_{ij}\in\left[0,1\right]$. In normalized decision matrix R, r_{ij} is calculated by

$$r_{ij}=\frac{x_{ij}}{\sum_{i=1}^{m}x_{ij}},\; i=1,...,m;\; j=1,...,n \tag{1}$$

The second step is to calculate entropy value e_j. In the n results, m evaluating criteria evaluation problem, the entropy of j-th criterion is defined as:

$$e_j=-k\sum_{i=1}^{m}r_{ij}ln(r_{ij})\quad,\qquad j=1,...,n \tag{2}$$

in which, $k = \dfrac{1}{\ln(m)}$, and suppose when $r_{ij} = 0$, $r_{ij}\ln(r_{ij}) = 0$.

The third step is to determine the weight of entropy of *j*-th result

$$w_j = \frac{1 - e_j}{n - \sum_{j=1}^{n} e_j}, \sum_{i=1}^{n} w_j = 1 \;\; j = 1,...,n \tag{3}$$

where w_j indicates the objective weight for *j*-th result.

3.2. TOPSIS Method

TOPSIS is one of the useful MCDM (Multi- Criteria Decision Making) techniques that are very simple and easy to implement, so that it is used when the user prefers a simpler weighting approach. TOPSIS method was first proposed by Hwang & Yoon [12]. The basic principle of TOPSIS method is that the chosen alternative should have the shortest distance from the ideal solution and the farthest distance from the negative-ideal solution [13]. The positive ideal solution is a solution that maximizes the benefit criteria and minimizes the cost criteria, whereas the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria. The TOPSIS method consists of the following steps:

(1) Construction of the decision matrix

TOPSIS Method builds on the assumption that *mxn* decision matrix D includes *m* alternatives and *n* criteria as follows:

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \end{array} \tag{4}$$

(2) Normalization of the decision matrix

The decision matrix is normalized by vector normalization as shown below:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^{2}}}, \;\; i = 1,...,m; \; j = 1,...,n \tag{5}$$

This results in normalized decision matrix as follows.

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}_{m \times n} \tag{6}$$

(3) Weighted normalized decision matrix is formed as:

$$v_{ij} = w_i * r_{ij}, \; i = 1,...,m; \; j = 1,...,n. \tag{7}$$

(4) PIS (positive ideal solution) and NIS (negative ideal solution) are determined as respectively,

$$A^* = \left(v_1^*, v_2^*, ..., v_j^*, ..., v_n^*\right) \quad \textit{maximum values,} \tag{8}$$

$$A^- = \left(v_1^-, v_2^-, ..., v_j^-, ..., v_n^-\right) \quad \textit{minimum values} \tag{9}$$

(5) The distance of each alternative from PIS and NIS is calculated as:

$$d_i^+ = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - v_j^+\right)^2}, i = 1,2,...,m \tag{10}$$

$$d_i^- = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^-)^2}, \quad i = 1,2,...,m \tag{11}$$

(6) The closeness coefficient of each alternative (CC_i) is calculated as:

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-} \tag{12}$$

(7) The ranking of alternatives is determined by comparing CC_i values.

4. Analysis and Findings

In this paper, the primary data were gathered through surveys that have been distributed to staff of Department of Construction Works of Eskisehir Osmangazi University. There are five options ranked by 1 - 5 as follows: 1 = not important, 2 = less important, 3 = moderate, 4 = important, 5 = very important. Distribution of demographic profile of staff with regard to gender, occupation and experience are shown in table 2.

The gender distribution is 87.1 % of male and 12.9 % of female. Regarding the occupation distribution of the staff; 9.7 % of the staff are architecture, 51.6 % of them are civil engineers/technicians, 19.4 % of them are mechanical engineers/technicians and 19.4 % of them are electrical engineers/technicians. The demographics on experience have five categories. 3.2 % of staff has less than 5 years' experience. 22.6 % of them have experience between 5 and 10 years, 12.9 % of them have experience between 10 and 15 years, 22.6 % of them have experience between 15 and 20 years, and 38.7 % of staff have 20 years or more experience.

Table 2. Demographic profile of staff

Variable	Category	Frequency	%
Gender	Female	4	12.9
	Male	27	87.1
Occupation	Architecture	3	9.7
	Civil Engineers/Technicians	16	51.6
	Mechanical Engineers/Technicians	6	19.4
	Electrical Engineers/Technicians	6	19.4
Experience	1-5 years	1	3.2
	5-10 years	7	22.6
	10-15 years	4	12.9
	15-20 years	7	22.6
	20 years – and over	12	38.7

Before applying TOPSIS method, staff's responses categorized by their importance. Table 3 shows the results of categorized survey questions according to their importance.

Table 3. Results of survey

Criteria	Not important 1.00	Less Important 2.00	Moderate 3.00	Important 4.00	Very Important 5.00
Financial Credibility	0	0	0	11	20
Financial Strength	0	0	0	10	21
Materials and Equipment	0	0	1	18	12
Experience of Technical Staff	0	0	0	10	21
Number of Technical Staff	0	2	0	18	11
Safety Plan and Safety Record	0	2	0	12	17
Termination of Construction Work	0	0	0	9	22
Construction Work Quality Ref.	0	2	0	15	14
Work Experience Document	0	0	1	19	11
Similar Work Experience	0	1	0	18	12
Lowest Bid	3	16	3	8	1
Length of Time in Const. Sector	0	9	0	22	0

Afterward, each cell of table 4 is divided by square root of related column sum. Obtained values are shown in table 4.

Table 4. Normalized decision matrix

Criteria	Not important 1.00	Less Important 2.00	Moderate 3.00	Important 4.00	Very Important 5.00
Financial Credibility	0.0000	0.0000	0.0000	2.3496	7.5837
Financial Strength	0.0000	0.0000	0.0000	1.9418	8.3610
Materials and Equipment	0.0000	0.0000	0.3015	6.2916	2.7301
Experience of Technical Staff	0.0000	0.0000	0.0000	1.9418	8.3610
Number of Technical Staff	0.0000	0.2138	0.0000	6.2916	2.2941
Safety Plan and Safety Record	0.0000	0.2138	0.0000	2.7962	5.4792
Termination of Construction Work	0.0000	0.0000	0.0000	1.5729	9.1763
Construction Work Quality Ref.	0.0000	0.2138	0.0000	4.3691	3.7160
Work Experience Document	0.0000	0.0000	0.3015	7.0100	2.2941
Similar Work Experience	0.0000	0.0535	0.0000	6.2916	2.7301
Lowest Bid	3.0000	13.6838	2.7136	1.2428	0.0190
Length of Time in Const. Sector	0.0000	4.3296	0.0000	9.3985	0.0000

Table 5. Entropy measures

	Not important 1.00	Less Important 2.00	Moderate 3.00	Important 4.00	Very Important 5.00
e_j	-1.3263	-16.4991	-0.7992	-33.9281	-38.0827
w_i	0.0227	0.1705	0.0175	0.3403	0.3808

Then, by using entropy method, objective weights of criteria were calculated. Using by Eqs. (2) and (3) entropy measure of each index is obtained. The obtained values of e_j and w_j are presented in table 5.

Table 6. Weighted normalized decision matrix

Criteria	Not important 1.00	Less Important 2.00	Moderate 3.00	Important 4.00	Very Important 5.00
Financial Credibility	0.0000	0.0000	0.0000	0.0727	0.1444
Financial Strength	0.0000	0.0000	0.0000	0.0661	0.1516
Materials and Equipment	0.0000	0.0000	0.0053	0.1189	0.0866
Experience of Technical Staff	0.0000	0.0000	0.0000	0.0661	0.1516
Number of Technical Staff	0.0000	0.0182	0.0000	0.1189	0.0794
Safety Plan and Safety Record	0.0000	0.0182	0.0000	0.0793	0.1227
Termination of Construction Work	0.0000	0.0000	0.0000	0.0595	0.1588
Construction Work Quality Ref.	0.0000	0.0182	0.0000	0.0991	0.1011
Work Experience Document	0.0000	0.0000	0.0053	0.1256	0.0794
Similar Work Experience	0.0000	0.0091	0.0000	0.1189	0.0866
Lowest Bid	0.0227	0.1458	0.0159	0.0529	0.0072
Length of Time in Const. Sector	0.0000	0.0820	0.0000	0.1454	0.0000

Table 7. Positive and negative ideal solutions

Criteria	Not Important 1.00	Less Important 2.00	Moderate 3.00	Important 4.00	Very Important 5.00
Positive Ideal	0.0227	0.1458	0.0159	0.1454	0.1588
Negative Ideal	0	0	0	0.0529	0

Table 8. Closeness coefficients and ranking

Criteria	d_i^+	d_i^-	CC_i	Rank
Financial Credibility	0.1786	0.1551	0.465	4
Financial Strength	0.1813	0.1620	0.472	3
Materials and Equipment	0.1793	0.1162	0.393	11
Experience of Technical Staff	0.1813	0.1620	0.472	2
Number of Technical Staff	0.1669	0.1118	0.401	10
Safety Plan and Safety Record	0.1623	0.1351	0.454	6
Termination of Construction Work	0.1845	0.1692	0.478	1
Construction Work Quality Ref.	0.1617	0.1200	0.426	7
Work Experience Document	0.1818	0.1149	0.387	12
Similar Work Experience	0.1715	0.1164	0.404	9
Lowest Bid	0.1891	0.1604	0.459	5
Length of Time in Const. Sector	0.1855	0.1323	0.416	8

To apply the TOPSIS method, the findings in tables 4 and 5 are used. The weighted normalized decision matrix is calculated using Eqs. (7), (8) and (9). Table 6 shows the results. According to Eqs. (10) and (11) the positive ideal and negative ideal solutions are calculated and they are given in table 7. Table 8 shows the distance of each determinant from the positive ideal solution and negative ideal solution. The ranking of the preference orders these determinants according to the closeness coefficient is shown in the final column of table 8.

5. Conclusion

One of the most important issues in construction process is the selection of right contractor. Traditional contractor's assessment and selection always deals with risk and a single criterion, namely lowest bid can be used in public works only. In competitive environment contractor selection must be performed according to multiple criteria.

As mentioned earlier, the current practice in Turkey can be regarded as "the lowest bidder among prequalified contractors is the winner". Recently, there has been a trend away from a lowest-bid wins principle and subjective judgment to a multi-criteria selection approach. In this paper, it is evaluated the importance of criteria which effect on contractor selection process in public buildings construction besides lowest bid. For this purpose, a survey is conducted to staff of Department of Construction Works of Eskisehir Osmangazi University. It is asked to survey respondents about importance degree of determined criteria in one to five scale. The results are analysed by Entropy and TOPSIS methods.

The analysis results show that "termination of construction work" criterion in contractor selection process is the most important one. "Lowest bid" criterion is ranked in fifth rank among twelve criteria. The results show that the taking consideration of other attributes of contractors in contractor selection process for public building works can be useful in evaluating experienced, capable and qualified candidate contractors and eliminating incompetent, inexperienced, or underfinanced contractors during the bidding process.

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