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# Assessment of Qualification Criteria Described in Public Procurement Law Code 4734 in Construction Works by Analytic Hierarchy Process (AHP)

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**Abstract**

Turkish public procurement law and secondary regulations describe tender evaluation in detail. In this system, bidders' capabilities on each qualification criteria are evaluated either as satisfied or not satisfied therefore final evaluation is solely price based. This method is criticized as incomplete and lacking consideration in terms of the contractor's ability to achieve simultaneously, time, cost, quality and safety standards. In this study, each qualification criteria is given a weight to be determined by group of experts in tender evaluation making tender evaluation a multi criteria decision making problem. Group AHP method is used to identify the weights of qualification criteria already in use.

## 1. INTRODUCTION

The complexity and adversity of the current construction industry aggravate the various risks and uncertainties faced by contractors, which influence their ultimate performance levels [1]. In contractor selection or tender evaluation, it should be meticulously examined that tenderer's economic, financial and technical standing promise to overcome the risks and deliver the project in time and budget.

In Turkish procurement practice, most frequently used procedure for selecting contractors has been open tendering where the lowest bidder is awarded the contract. This resulted in poor quality of delivery and budget overrun and sometimes in termination of contracts. Only recently, non-price factors have come into picture, which is still insufficient to ensure to deliver a project of demanded quality, in time and budget; because, the non-price factors are not related to the qualifications of tenderers. Indeed, contractor selection is a multi-criteria decision making (MCDM) problem which requires simultaneous evaluation of bidder's qualifications besides bid price.

This study aims to identify weights of qualification criteria on tender evaluation. As a MCDM tool, the analytical hierarchy process method, which is first introduced by Saaty, is employed. This method is widely used in various areas [2-6].

So far, no study has been come across about finding the weights of qualification criteria used in tenders implemented according to Public Procurement Law Code 4734 (PPL) by the method of AHP.

Nieto-Morote & Ruz-Villa presented a systematic prequalification procedure, based on Fuzzy Set Theory, whose main differences and advantages in comparison with other models are the use of an algorithm to handle the inconsistencies in the fuzzy preference relation when pair-wise comparison judgements are

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used and the use of linguistic assessment or exact assessment of performance of the contractors on qualitative or quantitative criterion [1].

Tama & Tummalab, formulated an AHP-based model and applied it to a real case study to examine its feasibility in selecting a vendor for a telecommunications system. The use of the proposed model indicated that it can be applied to improve the group decision making in selecting a vendor that satisfies customer specifications. Also, it was found that the decision process is systematic and that using the proposed AHP model can reduce the time taken to select a vendor [7].

El Sawalhi et al., used a Delphic Technique together with AHP utilizing pair-wise analysis to establish weights through a structured questionnaire. The established weights were used to develop a contractor's pre-qualification model using a hybrid technique by combining a neural network and a genetic algorithm [8].

Cheung et al. developed a selection method using Multi-Attribute Utility Technology (MAUT) and AHP. With the input of industrial experts, critical procurement selection criteria and procurement strategies commonly used in Hong Kong were identified. Against these criteria, utility factors corresponding to various procurement strategies were then assigned by the experts to create a utility factor table. To cater for individual project characteristics, the relative importance weightings of the selection criteria were assessed using the analytical hierarchy process. Final selection was then based on the highest utility value derived from the procurement strategies, taking into account the relative importance of the selection criteria. The use of the model is illustrated with actual data [9].

Jaskowski et al., suggested application of an extended fuzzy AHP method to the process of group decision making. This approach facilitates defining criteria weights by aggregation of decision makers' judgments. The model determined criteria weights for bidder assessment. The results showed that the proposed fuzzy AHP method is superior to the traditional AHP in terms of improved quality of criteria prioritization [10].
Supciller & Capraz, identified quality, cost, delivery and service criteria as the main criteria. In selecting main criteria and sub-criteria AHP was employed while in ranking suppliers TOPSIS was employed. They used Super Decisions 2.0.8 software for AHP and Microsoft Excel 2007 for TOPSIS [11].

Trivedi et al., developed a model using fuzzy AHP to rank contractors for housing projects. Triangular fuzzy numbers were considered to form a fuzzy comparison matrix for criteria and alternatives (contractors). Consequently a fuzzy score matrix is prepared to obtained crisp score (defuzzified value), which ultimately gives overall ratting of the alternatives (contractors) [12].

Kolekar & Kanade prepared a model for contractor selection using AHP & fuzzy group decision making method and results were evaluated by using an actual case study in infrastructure development [13].

Liu et al., developed a partial least square (PLS) path modeling for contractor selection. They established an indicator system of contractor selection on large scale construction projects. Second, they proposed a two-stage PLS path modeling combined with the maximization of deviations principle as an aggregation approach for performance evaluation. Finally, they compared the two-stage and typical PLS path modeling methods through a case study, which was conducted to validate the reliability of the new approach [14].

Mimović et al., pointed out an integrated application of the AHP and Bayesian analysis, in the sense that the Bayes' formula can improve the accuracy of input data for AHP, and vice versa, AHP can provide objectified inputs for the Bayesian formula in situations where the statistical estimates of probability are not possible. In this sense, the AHP can be considered as the Bayesian process that allows decision-makers to objectify their decisions and formalize the decision process through pairwise comparison of elements [15].

In this study, first, the qualification criteria in public procurement law and secondary regulation are identified. Second, a group of 20 experts is formed. Their opinions about criteria are evaluated by AHP to put each criterion with a weight in tender evaluation. All opinions are aggravated by geometric mean and arithmetic mean methods. The results are tabulated.

## 2. THE PREQUALIFICATION CRITERIA IN PUBLIC PROCUREMENT LAW CODE 4734

### 2.1. Qualification Criteria

Qualification criteria are divided into two main groups as economic & financial criteria and professional & technical criteria. There are numerous criteria and sub-criteria defined in PPL as professional and technical qualification. These criteria are cut down to 4 sub-criteria in secondary regulation. These criteria are listed in the Table 1.

***Table 1.*** *Qualification criteria*

| | | | |
|---|---|---|---|
| Qualification Criteria | Economic and Financial Criteria | Bank Statements | |
| | | Balance sheet (Financial ratios) | Current ratio |
| | | | Equity ratio |
| | | | Short term bank liability / equity |
| | | Overall turnover or volume of the work being carried out and completed by the tenderer relating to the construction works | |
| | Professional and Technical Criteria | Experience in similar works | |
| | | Facilities, Machinery, Devices and other equipment | |
| | | Quality management standards | |
| | | Environment management standards | |

Bank statements are required to show financial standing of the tenderer. The balance sheet of the tenderer which is obligatory to be published in accordance with the related legislation is demanded to see the financial health of tenderer. The implementing regulation seeks three ratios namely, current ratio, equity ratio and ratio of short term bank liabilities to equity.

Current ratio (CR) is used by lenders to determine whether a company has a sufficient level of liquidity to pay its liabilities. A current ratio of 1:1 is considered to be the absolute minimum level of acceptable liquidity, whereas a ratio closer to 2:1 is preferred [16]. Equity ratio (ER), the ratio of shareholders' equity to total assets is an investment leverage or solvency ratio that measures the amount of assets that are financed by owners' investments by comparing the total equity in the company to the total assets [17]. The third ratio is shows is an indicator of risk that tenderer may face in case it cannot pay short term bank loans in due time.

A statement of the tenderer's overall turnover (AT) or documents indicating the volume of the work being carried out and completed by the tenderer relating to the construction works (CCCW) is required by PPL. The criteria to meet as of PPL or implementing regulation are given in Table 2.

***Table 2.*** *Qualification thresholds*

| **Public Procurement Law** | **Bank Statement** | **Balance sheet** | | | **A.T or CCCW** |
|---|---|---|---|---|---|
| **Implementing Regulation** | | Current ratio | Equity Ratio | STBL/Equity | |
| **Formula** | | $\frac{\text{Current assets}}{\text{Current liabilities}}$ | $\frac{\text{Equity}}{\text{Assets}}$ | $\frac{\text{S.T. Bank liabilities}}{\text{Equity}}$ | |
| **Criteria** | 10 % of bid price | 75 % | 50 % | 15% | 25 or 15 % of bid price |

In the case of professional and technical qualification criteria, the following documents must be submitted by the tenderer to certify that they meet the required criteria.

a) Certificate of completion to prove experience in works contracts whose preliminary acceptance proceedings have been completed within the last fifteen years
b) Certificate of work status to prove the experience in works contracts whose preliminary acceptance proceedings have been completed, of which is supervised or managed at least in the ratio of 80% of the contract value within the last fifteen years,
c) Certificate of work supervising or management to prove the experience for the ongoing works contracts which have been completed flawlessly, supervised and managed at least in the ratio of 80% of the total contract value within the last fifteen years, provided that the initial contract value has been completed,

Additionally, in Article 62 of PPL, engineers or architects without work experience can use their diplomas to prove experience.

Another document to submit is the documents relating to facilities, machinery, devices and other equipment required for fulfilment of the work. Finally, quality system and environmental system related documents are required.

### 2.2. Evaluation of Tenders

Tenderers documents are examined to check whether they meet the economic and financial threshold and professional and technical threshold. This evaluation is a binary decision making. Contract is then awarded to one of the qualified tenderer who submitted the economically most advantageous tender.

The economically most advantageous tender is determined solely on the basis of price or together with the price by taking into account the non-price factors such as operation and maintenance costs, cost effectiveness, productivity, quality and technical merit [18]. However, the non-price factors are different from qualification criteria therefore the contractor selected this way does not necessarily mean that it is highly qualified.

Tenders are evaluated by commission according to Articles 36 through 39. The tender commission shall examine the tender envelopes in the order of submission. Envelopes that are not in compliance are recorded in the minutes and are not evaluated. Tenderers with incomplete documents or improper tender letters and tender securities are recorded in the minutes (PPL, Article 36).

If needed, the contracting authority may ask the tenderers to clarify their tenders on the unclear aspects of tenders (PPL, Article 37). In evaluating the tenders, the tenders of the tenderers whose documents are established to be incomplete or whose tender letters and tender securities are unduly submitted as of Article 36 are excluded from the evaluation proceedings. Following this first-evaluation and proceedings, the tenders of tenderers with complete and appropriate documents and appropriate tender letters and preliminary guarantees shall be held subject to a detailed evaluation. At this stage, the tenders shall be examined for their conformity with the qualification criteria determining the capacity of the tenderers to perform the contract, as well as with the conditions set forth in the tender documents and whether an arithmetical error exists in unit price charts. The tenders that are found ineligible and the tenders with arithmetic errors in unit price charts shall be disqualified (PPL, Article 37).

The tender commission shall evaluate the tenders in accordance with Article 37 and shall determine those that are abnormally low compared to the other tenders or the estimated cost determined by the contracting authority. Before rejecting these tenders, the commission shall request from the related tenderers, the details relating to components of the tender that are determined to be significant, in writing and within a specified period. Following the evaluation performed in accordance with Article 37 and 38, the contract shall be awarded to the tenderer who submitted the economically most advantageous tender shall be awarded with the contract. (PPL, Article 40)

The economically most advantageous tender is determined solely on the basis of price or together with the price by taking into account the non-price factors such as operation and maintenance costs, cost effectiveness, productivity, quality and technical merit (PPL, Article 40). The tender evaluation process is shown in Figure 1.

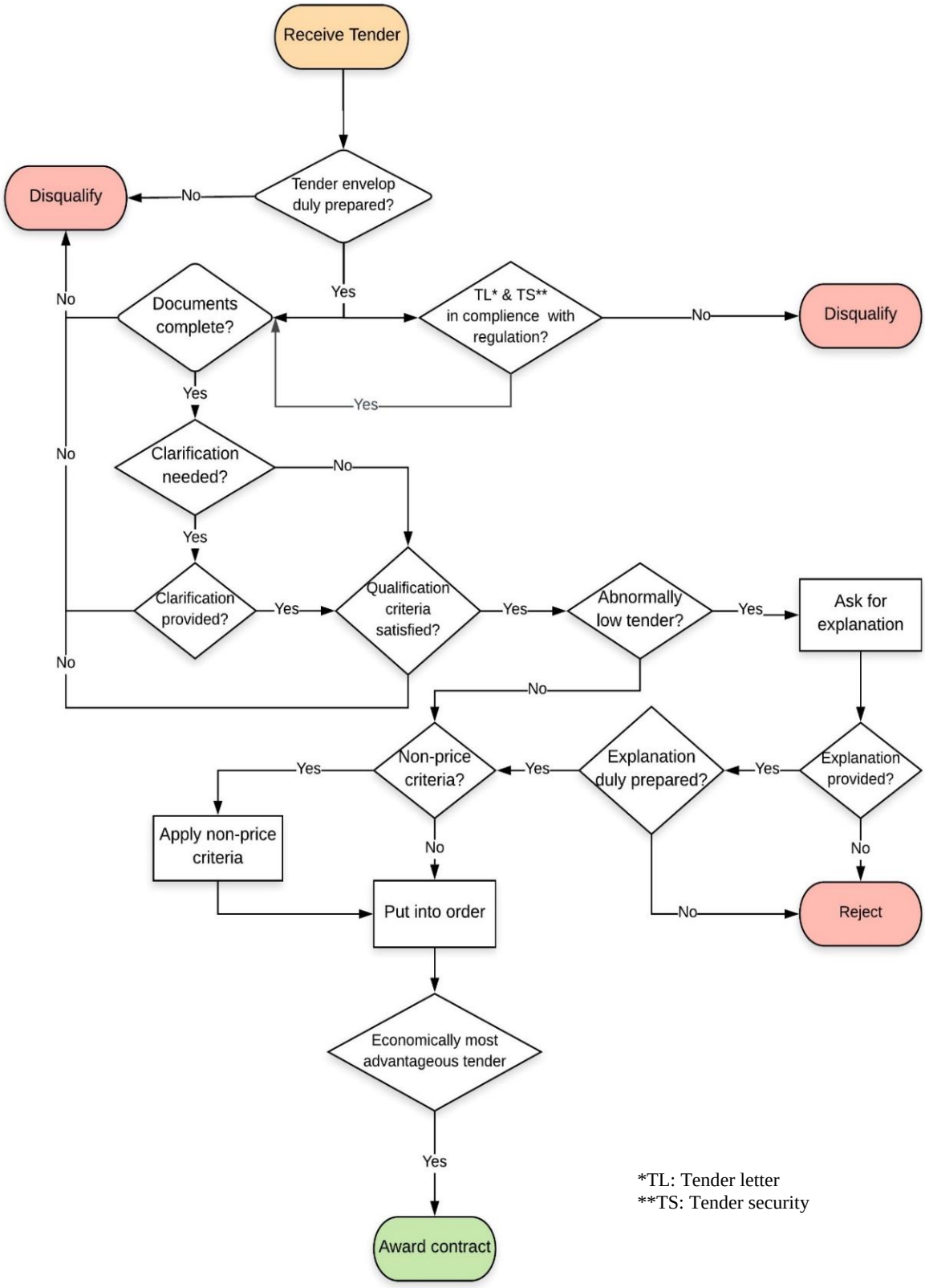


***Figure 1.*** *The tender evaluation process*

## 3. ANALYTIC HIERARCHY PROCESS

First introduced by Saaty [19] analytical hierarchy process is a multi-criteria decision technique that uses hierarchical structures to define a problem and then develop priorities for the alternatives based on the judgement of the user. The AHP utilizes three decision making steps:
(1) Given $i = 1, \ldots, m$ criteria, objectives etc., determine their respective weights $w_i$,
(2) For each element $i$, compare the elements and determine their weights $w_{ij}$ with respect to objective $i$,
(3) Determine the final element weights (priorities) by synthesizing

### 3.1. Axioms of AHP

*Axiom 1. The Reciprocal Axiom*

For all $A_i, A_j \in \kappa$ and $c \in ¥$

$$P_C(A_i, A_j) = {}^{1}\!\Big/\!_{P_C(A_i, A_j)} \tag{1}$$

Whenever a decision maker makes paired comparisons he/she needs to consider both members of the pair to judge the relative value. If one stone is judged to be five times heavier than another, then the other is automatically one fifth as heavy as the first because it participated in making the first judgment [19].

*Axiom 2: Homogeneity Axiom*

Given a hierarchy, $\mathfrak{H}$, $x \in \mathfrak{H}$ and $x \in L_k$ , $x^- \subseteq L_{k+1}$ is $\rho$-homogeneous for *k=1,…,h-1*. Homogeneity is essential for comparing similar things, as the mind tends to make large errors in comparing widely disparate elements. For example, a grain of sand cannot be compared with an orange according to size [20].

*Axiom 3: Synthesis Axiom*

Judgments about, or the priorities of, the elements in a hierarchy do not depend on lower level elements. This axiom is required for the principle of *hierarchic composition* to apply [20].

*Axiom 4: Expectations*

This axiom simply says that those thoughtful individuals who have reasons for their beliefs should make sure that their ideas are adequately represented for the outcome to match these expectations; i.e., all alternatives are represented in the hierarchy, as well as all criteria. It neither assumes rationality of the process nor that it can only accommodate a rational outlook. People have many expectations that are irrational [20].

Saaty [21] proposes decomposing the decision into the following steps to make a decision in an organized way to generate priorities:

1. Define the problem and determine the kind of knowledge sought.
2. Structure the decision hierarchy from the top with the goal of the decision, then the objectives from a broad perspective, through the intermediate levels (criteria on which subsequent elements depend) to the lowest level (which usually is a set of the alternatives).
3. Construct a set of pairwise comparison matrices. Each element in an upper level is used to compare the elements in the level immediately below with respect to it.
4. Use the priorities obtained from the comparisons to weigh the priorities in the level immediately below. Do this for every element. Then for each element in the level below add its weighed values

and obtain its overall or global priority. Continue this process of weighing and adding until the final priorities of the alternatives in the bottom most level are obtained.

For each attribute, and each pair of alternatives, specify preference in the form of a fraction between 1/9 and 9 (Table 3).

***Table 3.*** *The fundamental scale of absolute numbers [19, 22]*

| **Intensity of Importance** | **Definition** | **Explanation** |
|---|---|---|
| 1 | Equal importance | Two activities contribute equally to the objective |
| 3 | Weak importance of one over another | Experience and judgment slightly favor one activity over another |
| 5 | Essential or strong importance | Experience and judgment strongly favor one activity over another |
| 7 | Demonstrated importance | An activity is strongly favored, and its dominance demonstrated in practice |
| 9 | Absolute importance | The evidence favoring one activity over another is of the highest possible order of affirmation |
| 2,4,6,8 | Intermediate values between the two adjacent judgments | When compromise is needed |
| 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 when compared with *i* | |

The AHP users have to decompose their decision problem into a hierarchy of simpler sub-problems, which can be independently analyzed. These elements can be related and applied to any aspect of the decision problem: tangible and intangible, carefully measured and roughly estimated, well or poorly understood [23].

After all criteria have been compared with the priority scale pair by pair, a paired comparison matrix is being formed and a priority vector calculated [24].

$$A = (a_{1,1}) = \begin{bmatrix} a_{1,1} & a_{1,2} & . & . & a_{1,n} \\ a_{2,1} & a_{2,2} & . & . & a_{2,n} \\ . & . & . & . & . \\ . & . & . & . & . \\ a_{n,1} & a_{n,2} & . & . & a_{n,n} \end{bmatrix} \text{ (i,j=1,2,….,n)} \quad (2)$$

According to Saaty [21, 24], there are three steps in this stage to compute the Eigen vector of a matrix as;

*Step 1:* The values in each column are summed.

$$A = (a_{1,1}) = \frac{\begin{bmatrix} a_{1,1} & a_{1,2} & . & . & a_{1,n} \\ a_{2,1} & a_{2,2} & . & . & a_{2,n} \\ . & . & . & . & . \\ . & . & . & . & . \\ a_{n,1} & a_{n,2} & . & . & a_{n,n} \end{bmatrix}}{\sum_1^n a_{i,1} \quad \sum_1^n a_{i,2} \quad . \quad . \quad \sum_1^n a_{i,n}} \quad (3)$$

*Step 2:* Each element of the matrix is divided by its column total to obtain normalized matrix. The total of each column then becomes unity.

$$N = \begin{bmatrix} \frac{1}{\sum_1^n a_{i,1}} & \frac{a_{1,2}}{\sum_1^n a_{i,2}} & . & . & \frac{a_{1,n}}{\sum_1^n a_{i,n}} \\ \frac{a_{2,1}}{\sum_1^n a_{i,1}} & \frac{a_{2,2}}{\sum_1^n a_{i,2}} & . & . & \frac{a_{2,n}}{\sum_1^n a_{i,n}} \\ . & . & . & . & . \\ . & . & . & . & . \\ \frac{a_{n,1}}{\sum_1^n a_{i,1}} & \frac{a_{n,2}}{\sum_1^n a_{i,2}} & . & . & \frac{a_{n,n}}{\sum_1^n a_{i,n}} \end{bmatrix} \quad (4)$$

*Step 3:* The elements in each row are averaged to determine the priority of each criterion.

$$W = \begin{bmatrix} \frac{\sum_1^n a_{1,i}}{n} \\ \frac{\sum_1^n a_{2,i}}{n} \\ . \\ . \\ \frac{\sum_1^n a_{n,i}}{n} \end{bmatrix} \quad (5)$$

The final step of the AHP is the consistency check. Consistency check is made over a consistency ratio (*CR*), which can be defined as the reliability measure for the answers given to pair-wise comparisons.

First, consistency index (*CI*) is calculated by [24],

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (6)$$

In the formula, the principal eigenvector, $\lambda_{max}$, is calculated by summing the products between each element of Eigen vector and the sum of columns of comparison matrix.

Consistency ratio (*CR*) is the found by [25, 26],

$$CR = \frac{\mathrm{CI}}{RI} \quad (7)$$

where *RI* is the random index. Saaty gives *RI* values for corresponding *n* values. For the values of n from 3 to 15, the corresponding *RI* values are given in Table 4.

***Table 4.*** *Saaty Random Index [22, 27]*

| *n* | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *RI* | 0.58 | 0.89 | 1.11 | 1.25 | 1.35 | 1.40 | 1.45 | 1.49 | 1.52 | 1.54 | 1.56 | 1.58 | 1.59 |

### 3.2. Group Decision

There are several aggregation methods such as arithmetic mean, geometric mean, squared Euclidian distance. In this study, arithmetic mean and geometric mean method are used. Actually, due to the nature of scale, geometric mean for aggregation is far more suitable than the arithmetic mean.

In arithmetic mean method,

$$a_{i,j} = \frac{\sum_{k=1}^{n} \left(\mathrm{a}_{i,j}\right)_n}{n} \quad (8)$$

in geometric mean method,

$$a_{i,j} = \left(\prod_1^n a_{i,j}\right)^{1/n} \quad (9)$$

formulae are used.

## 4. THE APPLICATION

*Step 1:* The hierarchy tree of components consisting of bid price and qualification criteria is depicted as below. There are three levels in the tree. In the first level, the main criteria, which are written on PPL article 10 as a subheading and the bid price are placed. In the second level, the components of the main economic and financial criteria and professional and technical criteria as placed. These criteria also exist in PPL. In the third level, the financial ratios are placed. These ratios, although not written on the law, are mandatory due to the secondary legislation. The decision tree is depicted in Figure 2.

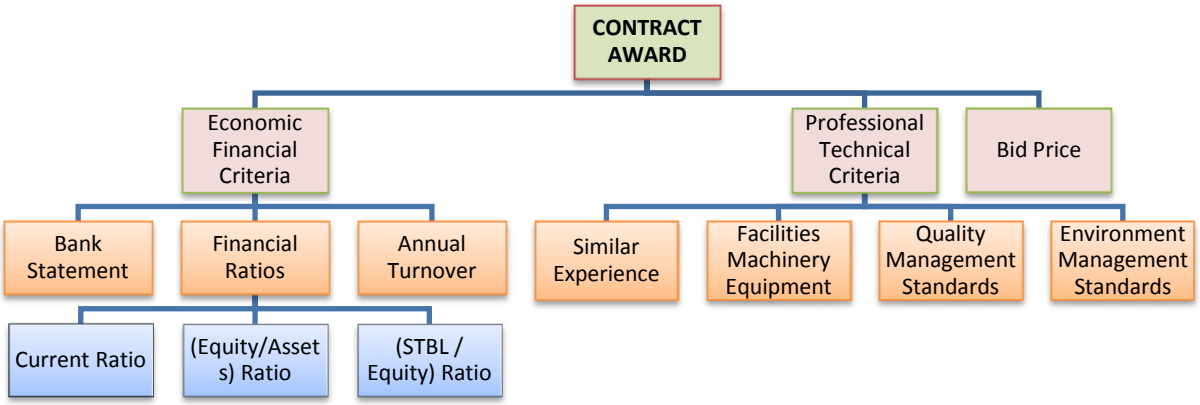


***Figure 2.*** *The decision tree*

### 4.1. Survey

20 public procurement specialists are selected to participate in the survey. The professional experience distribution of the attendees is graphed in the pie chart below.

As seen from the graph in Figure 3, the least experience duration is 5-10 year, the largest experience is 30-35 year and half of the attendees have 10-15 years' experience.

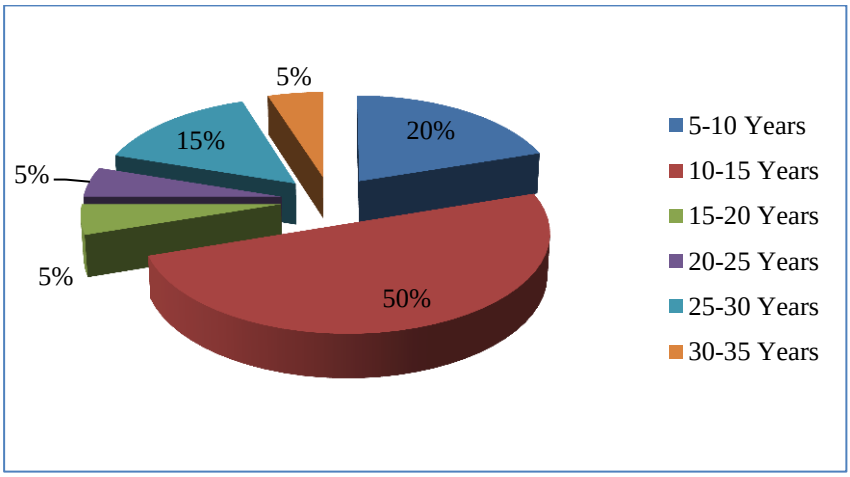


***Figure 3.*** *Distribution of professional experience*

On the other hand, the distribution of the number of tenders that the attendees have reviewed or checked is given in Figure 4. It is seen that 30 % of attendees have reviewed or checked more than 1000 tenders.

Also, all attendees have either reviewed or checked 100 or more tenders. This shows that the attendees are all well experienced, have sound background on procurement and therefore can provide valuable opinion about criteria assessment.

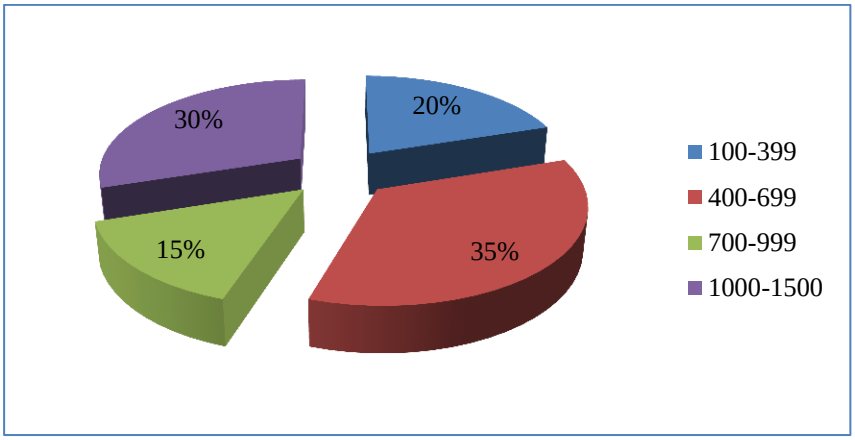


***Figure 4.*** *Distribution of number of tenders reviewed or checked by attendees*

3 comparisons at level 1 about main criteria, 3 comparisons at level 2 about economic and financial sub-criteria, 6 comparisons at level 2 about professional and financial sub-criteria and finally 3 comparisons at level 3 about economic and financial sub-criteria are requested from the attendees.

The entries in Table 5 respond to the question which criterion is more important with respect to choosing the best contractor. The criteria are:

a) Economic and financial criteria (EF)
b) Professional and technical criteria (PT)
c) Bid price (BP)

***Table 5.*** *Comparison matrices at level 1*

| | **EF** | **PT** | **BP** | **W** | **EF** | **PT** | **BP** | **W** | **EF** | **PT** | **BP** | **W** | **EF** | **PT** | **BP** | **W** | **EF** | **PT** | **BP** | **W** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Expert 1** | | | | **Expert 2** | | | | **Expert 3** | | | | **Expert 4** | | | | **Expert 5** | | | |
| **EF** | 1 | | | 40.00 | 1 | | | 16.40 | 1 | | | 6.40 | 1 | | | 9.10 | 1 | | | 8.00 |
| **PT** | 1/2 | 1 | | 20.00 | 2 | 1 | | 29.70 | 6 | 1 | | 29.00 | 5 | 1 | | 45.50 | 4 | 1 | | 26.50 |
| **BP** | 1 | 2 | 1 | 40.00 | 3 | 2 | 1 | 53.90 | 8 | 3 | 1 | 64.60 | 5 | 1 | 1 | 45.50 | 7 | 3 | 1 | 65.50 |
| | **Expert 6** | | | | **Expert 7** | | | | **Expert 8** | | | | **Expert 9** | | | | **Expert 10** | | | |
| **EF** | 1 | | | 12.30 | 1 | | | 9.30 | 1 | | | 7.70 | 1 | | | 7.90 | 1 | | | 12.50 |
| **PT** | 3 | 1 | | 32.00 | 3 | 1 | | 22.10 | 3 | 1 | | 18.60 | 3 | 1 | | 21.60 | 1 | 1 | | 12.50 |
| **BP** | 4 | 2 | 1 | 55.70 | 6 | 4 | 1 | 68.50 | 8 | 5 | 1 | 73.70 | 8 | 4 | 1 | 71.50 | 6 | 6 | 1 | 75.00 |
| | **Expert 11** | | | | **Expert 12** | | | | **Expert 13** | | | | **Expert 14** | | | | **Expert 15** | | | |
| **EF** | 1 | | | 9.09 | 1 | | | 11.11 | 1 | | | 16.38 | 1 | | | 10.00 | 1 | | | 10.66 |
| **PT** | 1 | 1 | | 9.09 | 1 | 1 | | 11.11 | 2 | 1 | | 29.73 | 1 | 1 | | 10.00 | 2 | 1 | | 19.35 |
| **BP** | 9 | 9 | 1 | 81.82 | 7 | 7 | 1 | 77.78 | 3 | 2 | 1 | 53.90 | 8 | 8 | 1 | 80.00 | 6 | 4 | 1 | 69.99 |
| | **Expert 16** | | | | **Expert 17** | | | | **Expert 18** | | | | **Expert 19** | | | | **Expert 20** | | | |
| **EF** | 1 | | | 7.38 | 1 | | | 6.64 | 1 | | | 10.96 | 1 | | | 7.89 | 1 | | | 8.33 |
| **PT** | 4 | 1 | | 25.72 | 7 | 1 | | 57.06 | 5 | 1 | | 58.13 | 3 | 1 | | 20.64 | 3 | 1 | | 19.32 |
| **BP** | 8 | 3 | 1 | 66.90 | 7 | 1 | 1 | 36.31 | 3 | ½ | 1 | 30.92 | 8 | 4 | 1 | 71.46 | 7 | 5 | 1 | 72.35 |

The entries in Table 6 respond to the question which criterion is more important with respect to showing the economic and financial strength of the tenderer. The criteria are:

a) Bank statement (BS)
b) Financial ratios (FR)
c) Annual turnover (AT)

***Table 6.*** *Comparison matrices at level 2 for economic and financial criteria*

| | BS | FR | AT | W | BS | FR | AT | W | BS | FR | AT | W | BS | FR | AT | W | BS | FR | AT | W |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Expert 1** | | | | **Expert 2** | | | | **Expert 3** | | | | **Expert 4** | | | | **Expert 5** | | | |
| **BS** | 1 | | | 10.62 | 1 | | | 23.95 | 1 | | | 5.26 | 1 | | | 6.67 | 1 | | | 6.67 |
| **FR** | 3 | 1 | | 26.05 | 3 | 1 | | 62.32 | 9 | 1 | | 47.37 | 7 | 1 | | 46.67 | 7 | 1 | | 46.67 |
| **AT** | 5 | 3 | 1 | 63.33 | ½ | 1/4 | 1 | 13.73 | 9 | 1 | 1 | 47.37 | 7 | 1 | 1 | 46.67 | 7 | 1 | 1 | 46.67 |
| | **Expert 6** | | | | **Expert 7** | | | | **Expert 8** | | | | **Expert 9** | | | | **Expert 10** | | | |
| **BS** | 1 | | | 6.67 | 1 | | | 6.54 | 1 | | | 6.83 | 1 | | | 7.03 | 1 | | | 5.88 |
| **FR** | 7 | 1 | | 46.67 | 6 | 1 | | 34.12 | 8 | 1 | | 65.71 | 6 | 1 | | 34.96 | 6 | 1 | | 25.07 |
| **AT** | 7 | 1 | 1 | 46.67 | 8 | 2 | 1 | 59.34 | 5 | 1/3 | 1 | 27.46 | 7 | 2 | 1 | 58.01 | 9 | 4 | 1 | 69.05 |
| | **Expert 11** | | | | **Expert 12** | | | | **Expert 13** | | | | **Expert 14** | | | | **Expert 15** | | | |
| **BS** | 1 | | | 5.48 | 1 | | | 5.26 | 1 | | | 53.90 | 1 | | | 7.82 | 1 | | | 7.89 |
| **FR** | 9 | 1 | | 58.69 | 9 | 1 | | 47.37 | 1/3 | 1 | | 16.38 | 7 | 1 | | 48.66 | 8 | 1 | | 71.46 |
| **AT** | 8 | 1/2 | 1 | 35.83 | 9 | 1 | 1 | 47.37 | ½ | 2 | 1 | 29.73 | 5 | 1 | 1 | 43.53 | 3 | 1/4 | 1 | 20.64 |
| | **Expert 16** | | | | **Expert 17** | | | | **Expert 18** | | | | **Expert 19** | | | | **Expert 20** | | | |
| **BS** | 1 | | | 11.11 | 1 | | | 5.77 | 1 | | | 6.54 | 1 | | | 5.98 | 1 | | | 5.98 |
| **FR** | 4 | 1 | | 44.44 | 9 | 1 | | 59.55 | 8 | 1 | | 59.34 | 9 | 1 | | 65.83 | 6 | 1 | | 28.19 |
| **AT** | 4 | 1 | 1 | 44.44 | 7 | 1/2 | 1 | 34.68 | 6 | ½ | 1 | 34.12 | 6 | 1/3 | 1 | 28.19 | 9 | 3 | 1 | 65.83 |

The entries in Table 7 respond to the question which criterion is more important with respect to showing the professional and technical strength of the tenderer. The criteria are:

a) Similar experience (SE)
b) Facilities, machines and other equipment (FM)
c) Quality management system certificate (QM)
d) Environment management system certificate (EM)

***Table 7.*** *Comparison matrices at level 2 for professional and technical criteria*

| | SE | FM | QM | EM | W | SE | FM | QM | EM | W | SE | FM | QM | EM | W | SE | FM | QM | EM | W |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Expert 1** | | | | | **Expert 2** | | | | | **Expert 3** | | | | | **Expert 4** | | | | |
| **SE** | 1 | | | | 32.58 | 1 | | | | 44.86 | 1 | | | | 59.50 | 1 | | | | 64.89 |
| **FM** | 2 | 1 | | | 53.72 | 1/5 | 1 | | | 8.20 | 1/3 | 1 | | | 27.61 | 1/5 | 1 | | | 20.60 |
| **QM** | 1/5 | 1/7 | 1 | | 8.30 | ½ | 3 | 1 | | 23.47 | 1/8 | 1/5 | 1 | | 6.44 | 1/7 | 1/3 | 1 | | 7.57 |
| **EM** | 1/6 | 1/8 | 1/2 | 1 | 5.40 | ½ | 3 | 1 | 1 | 23.47 | 1/8 | 1/5 | 1 | 1 | 6.44 | 1/8 | 1/4 | 1 | 1 | 6.95 |
| | **Expert 5** | | | | | **Expert 6** | | | | | **Expert 7** | | | | | **Expert 8** | | | | |
| **SE** | 1 | | | | 60.68 | 1 | | | | 57.37 | 1 | | | | 58.34 | 1 | | | | 65.16 |
| **FM** | 1/3 | 1 | | | 23.00 | 1/3 | 1 | | | 22.90 | 1/3 | 1 | | | 23.99 | ¼ | 1 | | | 22.12 |
| **QM** | 1/7 | 1/3 | 1 | | 8.16 | 1/5 | 1/2 | 1 | | 13.61 | 1/6 | 1/3 | 1 | | 8.83 | 1/9 | 1/4 | 1 | | 6.36 |
| **EM** | 1/7 | 1/3 | 1 | 1 | 8.16 | 1/7 | 1/4 | 1/3 | 1 | 6.11 | 1/6 | 1/3 | 1 | 1 | 8.83 | 1/9 | 1/4 | 1 | 1 | 6.36 |
| | **Expert 9** | | | | | **Expert 10** | | | | | **Expert 11** | | | | | **Expert 12** | | | | |
| **SE** | 1 | | | | 59.40 | 1 | | | | 61.24 | 1 | | | | 59.40 | 1 | | | | 61.24 |
| **FM** | 1/3 | 1 | | | 27.99 | 1/3 | 1 | | | 26.66 | 1/3 | 1 | | | 27.99 | 1/3 | 1 | | | 26.66 |
| **QM** | 1/8 | 1/5 | 1 | | 7.64 | 1/9 | 1/5 | 1 | | 6.05 | 1/8 | 1/5 | 1 | | 7.64 | 1/9 | 1/5 | 1 | | 6.05 |
| **EM** | 1/9 | 1/6 | 1/2 | 1 | 4.98 | 1/9 | 1/5 | 1 | 1 | 6.05 | 1/9 | 1/6 | 1/2 | 1 | 4.98 | 1/9 | 1/5 | 1 | 1 | 6.05 |
| | **Expert 13** | | | | | **Expert 14** | | | | | **Expert 15** | | | | | **Expert 16** | | | | |
| **SE** | 1 | | | | 55.54 | 1 | | | | 29.64 | 1 | | | | 46.58 | 1 | | | | 62.08 |
| **FM** | ½ | 1 | | | 31.58 | 1 | 1 | | | 24.64 | 1/2 | 1 | | | 27.71 | 1/3 | 1 | | | 20.50 |
| **QM** | 1/8 | 1/5 | 1 | | 7.79 | ½ | 1 | 1 | | 21.07 | 1/3 | 1/2 | 1 | | 16.11 | 1/7 | 1/2 | 1 | | 10.77 |
| **EM** | 1/9 | 1/6 | 1/2 | 1 | 5.09 | 1 | 1 | 1 | 1 | 24.64 | 1/4 | 1/3 | 1/2 | 1 | 9.60 | 1/8 | 1/3 | 1/2 | 1 | 6.65 |
| | **Expert 17** | | | | | **Expert 18** | | | | | **Expert 19** | | | | | **Expert 20** | | | | |
| **SE** | 1 | | | | 53.99 | 1 | | | | 55.21 | 1 | | | | 62.93 | 1 | | | | 10.26 |
| **FM** | 1/3 | 1 | | | 29.32 | ½ | 1 | | | 29.53 | ¼ | 1 | | | 21.78 | 1/3 | 1 | | | 4.67 |
| **QM** | 1/5 | 1/3 | 1 | | 10.56 | 1/7 | 1/4 | 1 | | 7.63 | 1/7 | 1/3 | 1 | | 9.35 | 5 | 8 | 1 | | 42.53 |
| **EM** | 1/6 | 1/7 | 1/2 | 1 | 6.13 | 1/7 | 1/4 | 1 | 1 | 7.63 | 1/8 | 1/4 | 1/2 | 1 | 5.93 | 5 | 8 | 1 | 1 | 42.53 |

The entries in Table 8 respond to the question which criterion is more important with respect to showing the economic and financial strength of the tenderer. The criteria are:

a) Current ratio (CR)
b) Equity ratio (ER)
c) Short term bank loans to equity ratio (SE)

***Table 8.*** *Comparison matrices at level 3*

| | **CR** | **ER** | **SE** | **W** | **CR** | **ER** | **SE** | **W** | **CR** | **ER** | **SE** | **W** | **CR** | **ER** | **SE** | **W** | **CR** | **ER** | **SE** | **W** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Expert 1** | | | | **Expert 2** | | | | **Expert 3** | | | | **Expert 4** | | | | **Expert 5** | | | |
| **CR** | 1 | | | 17.49 | 1 | | | 25.00 | 1 | | | 40.00 | 1 | | | 66.67 | 1 | | | 7.03 |
| **ER** | 4 | 1 | | 63.27 | 1 | 1 | | 25.00 | 1 | 1 | | 40.00 | 1/3 | 1 | | 22.22 | 6 | 1 | | 34.96 |
| **SE** | 1 | 1/3 | 1 | 19.24 | 2 | 2 | 1 | 50.00 | 1/2 | ½ | 1 | 20.00 | 1/6 | ½ | 1 | 11.11 | 7 | 2 | 1 | 58.01 |
| | **Expert 6** | | | | **Expert 7** | | | | **Expert 8** | | | | **Expert 9** | | | | **Expert 10** | | | |
| **CR** | 1 | | | 20.14 | 1 | | | 8.19 | 1 | | | 7.55 | 1 | | | 14.29 | 1 | | | 8.69 |
| **ER** | 1/2 | 1 | | 11.79 | 6 | 1 | | 57.50 | 5 | 1 | | 33.38 | 4 | 1 | | 57.14 | 4 | 1 | | 27.37 |
| **SE** | 1/4 | 5 | 1 | 68.06 | 5 | 1/2 | 1 | 34.31 | 7 | 2 | 1 | 59.07 | 2 | ½ | 1 | 28.57 | 6 | 3 | 1 | 63.93 |
| | **Expert 11** | | | | **Expert 12** | | | | **Expert 13** | | | | **Expert 14** | | | | **Expert 15** | | | |
| **CR** | 1 | | | 53.90 | 1 | | | 33.33 | 1 | | | 53.90 | 1 | | | 20.64 | 1 | | | 23.95 |
| **ER** | 1/3 | 1 | | 16.38 | 1 | 1 | | 33.33 | 1/2 | 1 | | 29.73 | 1/3 | 1 | | 7.89 | 3 | 1 | | 62.32 |
| **SE** | 1/2 | 2 | 1 | 29.73 | 1 | 1 | 1 | 33.33 | 1/3 | ½ | 1 | 16.38 | 4 | 8 | 1 | 71.46 | 1/2 | 1/4 | 1 | 13.73 |
| | **Expert 16** | | | | **Expert 17** | | | | **Expert 18** | | | | **Expert 19** | | | | **Expert 20** | | | |
| **CR** | 1 | | | 21.06 | 1 | | | 13.73 | 1 | | | 62.32 | 1 | | | 72.25 | 1 | | | 10.00 |
| **ER** | 3 | 1 | | 54.85 | 4 | 1 | | 62.32 | 1/3 | 1 | | 29.95 | 1/5 | 1 | | 17.41 | 3 | 1 | | 30.00 |
| **SE** | 1 | 1/2 | 1 | 24.09 | 2 | 1/3 | 1 | 23.95 | 1/4 | ½ | 1 | 13.73 | 1/6 | ½ | 1 | 10.33 | 6 | 2 | 1 | 60.00 |

### 4.2. Group opinion

Two methods are used to aggregate individual opinions; arithmetic mean and geometric mean. However, due to the comparison scale used, geometric mean gives more consistent results. At all levels, weight in parenthesis shows the weight according to arithmetic mean.

At level 1, the most important component of a tender is bid price. The group gives 64.91 (68.06) % weight. For construction works, it is expected that professional and technical criteria have more importance than economic and technical criteria. The results of survey also conforms the expectation. The professional and technical criteria have 24.21 (22.61) % weight while the economic and financial criteria have 10.88 (9.33) % weight. The outcomes are given in Table 9. The comparisons of results for arithmetic and geometric mean methods are given in Figure 5.

***Table 9.*** *Group comparison matrix at level 1*

| | **EF** | **PT** | **BP** | **W** | **EF** | **PT** | **BP** | **W** |
|---|---|---|---|---|---|---|---|---|
| | **Arithmetic Mean** | | | | **Geometric Mean** | | | |
| **EF** | 1 | | | 9.33 | 1 | | | 10.88 |
| **PT** | 2.98 | 1 | | 22.61 | 2.47 | 1 | | 24.21 |
| **BP** | 6.10 | 3.75 | 1 | 68.06 | 5.51 | 2.92 | 1 | 64.91 |
| $\lambda_{max}$ | 3.0409278 | | | | 3.0070769 | | | |
| **CI** | 0.0204639 | | | | 0.0035385 | | | |
| **CR** | 0.58 | | | | 0.58 | | | |
| **C** | 3.53 | | | | 0.61 | | | |

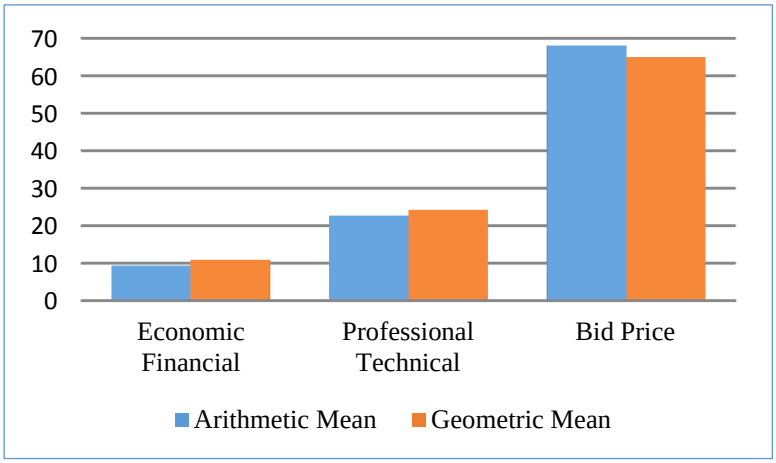


***Figure 5.*** *Comparison of weights at level 1*

At level 2, for economic and financial criteria, two sub-criteria, namely financial ratios and annual turnover have almost equal weight. This is due to the belief that bank statements can be obtained not regarding financial standings. The weight of financial ratios have 47.70 (43.07) % weight while annual turnover (or completed or continuing construction works) has 43.71 (49.60) % weight. The outcomes are given in Table 10. The comparisons of results for arithmetic and geometric mean methods are given in Figure 6.

***Table 10.*** *Group comparison matrix at level 2 for economic and financial criteria*

| | **BS** | **FR** | **AT** | **W** | **BS** | **FR** | **AT** | **W** |
|---|---|---|---|---|---|---|---|---|
| | **Arithmetic Mean** | | | | **Geometric Mean** | | | |
| **BS** | 1 | | | 7.34 | 1 | | | 8.59 |
| **FR** | 6.57 | 1 | | 43.07 | 2.47 | 1 | | 47.70 |
| **AT** | 6.10 | 1.28 | 1 | 49.60 | 5.51 | 2.92 | 1 | 43.71 |
| $\lambda_{max}$ | 3.0116299 | | | | 3.00032761 | | | |
| **CI** | 0.005815 | | | | 0.0001638 | | | |
| **CR** | 0.58 | | | | 0.58 | | | |
| **C** | 1.00 | | | | 0.03 | | | |

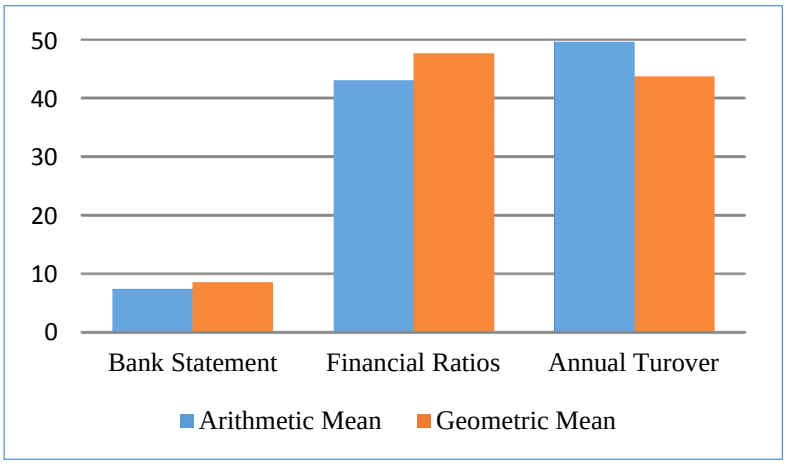


***Figure 6.*** *Comparison of weights at level 2 for economic and financial criteria*

At level 2, for professional and technical criteria, the foremost criterion is similar experience by 55.02 (42.82) %. The second important sub-criterion is facilities, machines and equipment by 25.12 (21.00) %. The outcomes for professional and technical criteria are given in Table 11. The comparisons of results for arithmetic and geometric mean methods are given in Figure 7.

***Table 11.*** *Group comparison matrix at level 2 for professional and technical criteria*

| | **SE** | **FM** | **QM** | **EM** | **W** | **SE** | **FM** | **QM** | **EM** | **W** |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Arithmetic Mean** | | | | | **Geometric Mean** | | | | |
| **SE** | 1 | | | | 42.82 | 1 | | | | 55.02 |
| **FM** | 0.45 | 1 | | | 21.00 | 0.38 | 1 | | | 25.12 |
| **QM** | 0.43 | 0.85 | 1 | | 19.38 | 0.20 | 0.39 | 1 | | 11.03 |
| **EM** | 0.44 | 0.80 | 0.77 | 1 | 16.80 | 0.19 | 0.33 | 0.72 | 1 | 8.83 |
| $\lambda_{max}$ | 4.011108875 | | | | | 4.023930296 | | | | |
| **CI** | 0.003703 | | | | | 0.0079768 | | | | |
| **CR** | 0.89 | | | | | 0.89 | | | | |
| **C** | 0.42 | | | | | 0.90 | | | | |

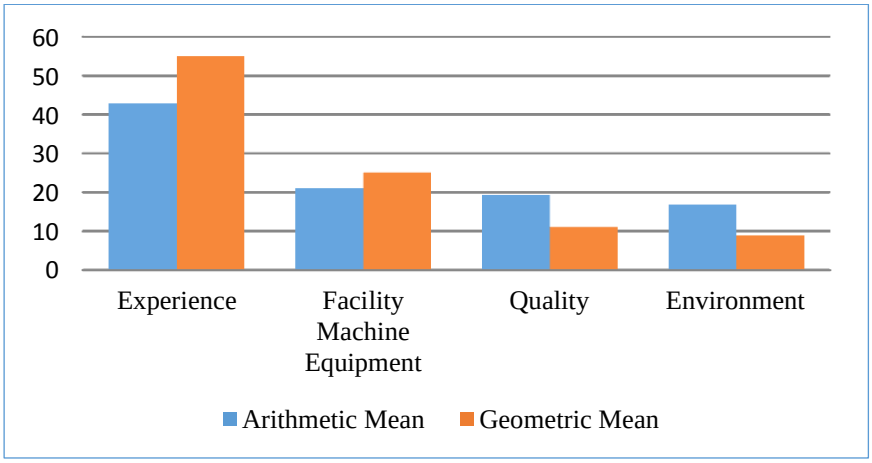


***Figure 7.*** *Comparison of weights at level 2 for professional and technical criteria*

At level 3, only the financial ratios are judged. The group thinks that tenderer's short-term bank loans are great threat to the continuation of the project. With this consideration, ratio of short term bank loans to equity has foremost weight. It has 64.91 (48.36) % weight, while equity ratio has 24.21 (34.81) % weight. The differences in weights by aggregation methods show that the attendees have very different opinions about these sub-criteria. The outcomes for the financial ratios are given in Table 12. The comparisons of results for arithmetic and geometric mean methods are given in Figure 8.

***Table 12.*** *Group comparison matrix at level 3*

| | **CR** | **ER** | **S/E** | **W** | **CR** | **ER** | **S/E** | **W** |
|---|---|---|---|---|---|---|---|---|
| | **Arithmetic Mean** | | | | **Geometric Mean** | | | |
| **CR** | 1 | | | 16.84 | 1 | | | 10.88 |
| **ER** | 2.38 | 1 | | 34.81 | 2.47 | 1 | | 24.21 |
| **S/E** | 2.52 | 1.60 | 1 | 48.36 | 5.51 | 2.92 | 1 | 64.91 |
| $\lambda_{max}$ | 3.01858719 | | | | 3.00000012 | | | |
| **CI** | 0.0092936 | | | | 5.905E-8 | | | |
| **CR** | 0.58 | | | | 0.58 | | | |
| **C** | 1.60 | | | | 0.00 | | | |

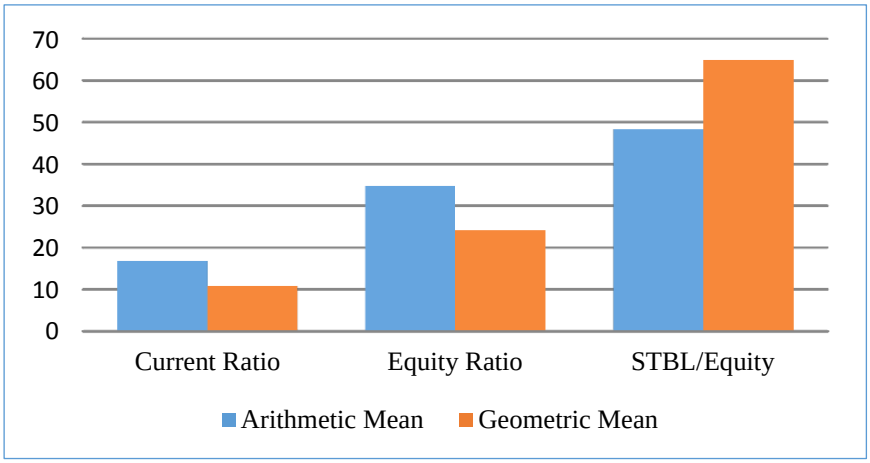


***Figure 8.*** *Comparison of weights at level 3*

Finally, the effect of each sub-criterion on tender evaluation is found by multiplying each criterion by the weight of upper level. The calculations and their results are tabulated Table 13.

***Table 13.*** *Weights of all criteria on tender evaluation*

| **Level 1** | | **Level 2** | | **Level 3** | | **Overall** |
|---|---|---|---|---|---|---|
| Criterion | Weight (%) | Criterion | Weight (%) | Criterion | Weight (%) | Weight (%) |
| **EF** | 10.88 | **BS** | 8.59 | | | (10.88x8.59/100) = **0.93** |
| | | **FR** | 47.70 | **CR** | 26.81 | (10.88x47.70x26.81/10000) = **1.39** |
| | | | | **ER** | 37.39 | (10.88x47.70x37.39/10000) = **1.94** |
| | | | | **S/E** | 35.80 | (10.88x47.70x35.80/10000) = **1.86** |
| | | **AT** | 43.71 | | | (10.88x43.71/100) = **4.76** |
| **PT** | 24.21 | **SE** | 55.02 | | | (24.21x55.02/100) = **13.32** |
| | | **FM** | 25.12 | | | (24.21x25.12/100) = **6.08** |
| | | **QM** | 11.03 | | | (24.21x11.03/100) = **2.67** |
| | | **EM** | 8.83 | | | (24.21x8.83/100) = **2.14** |
| **BP** | 64.91 | | | | | **64.91** |

The distribution of all criteria is shown in the chart in Figure 9. Although individual expert opinions differ enormously for some criteria, as far as wisdom of crowd is taken into account, the weight of qualification criteria on tender evaluation is 35.09 % which is about half as important as bid price. This is an important outcome because the regulation in force ignores the effect of qualification criteria on project implementation.

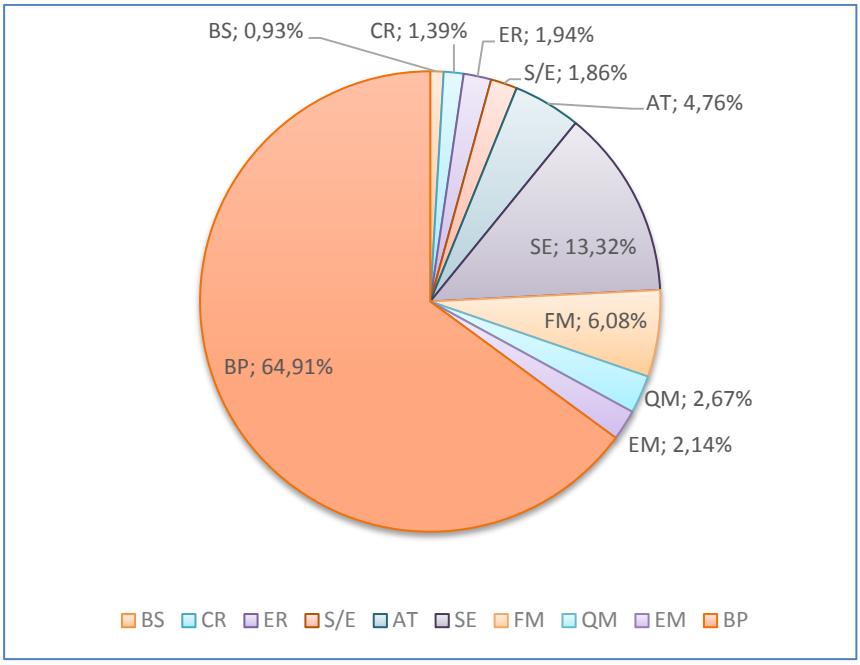


***Figure 9.*** *Distribution of weights of each criterion*

## 5. CONCLUSION

In Turkish procurement practice, economic-financial and professional-technical qualifications of tenderers do not have effect on determining economically most advantageous tender. Evaluating any tender without giving credit to qualifications of tenderers is insufficient to ensure to deliver a project of demanded quality, in time and budget. The survey in this study about opinions of 20 professionals having title expert, head of group and head of department showed that each criterion existing in PPL and IR needs to have a weight in determining economically most advantageous tender. As a MCDM tool, AHP is employed in the survey. To obtain group's opinion from individual opinions geometric mean is applied which gives more consistent results for the scale applied. According to groups' opinion, the nine sub-criteria must have 35.09 % effect on evaluation of tenders. The most important sub-criterion is similar experience having 13.32 % weight and the most important economic and financial sub-criterion is annual turnover having 4.76 % weight. Professional and technical criteria have 24.21 % total weight; economical and financial criteria have 10.88 % total weight.

This study constitutes first step in an alternative method development for tender evaluation for construction works. There are also other MCDM methods to employ and compare results. The next step is evaluation of alternatives that is how tenderer's qualifications should be put into evaluation process.

## CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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