Cost Analysis of Water Quality Assessment Using Multi-Criteria Decision-Making Approach

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Abstract

In modern competitive markets, cost and quality parameters are the two main factors. So, it is essential to study their relationship, especially in leading industries such as urban public service companies. Consequently, manufacturers always try to reduce production costs and improve products quality and services at consumer expectations. Also, the concerns of the new century in the field of fresh water and the reduction of its resources related to global warming have increased the costs of quality and supply of freshwater. Therefore, in this research, in order to estimate the quality costs in the field of water resources and wastewater management and identify the option that creates the most cost, in the first step, the "Prevention, Appraisal, and Failure (PAF)" model was used to select cost-imposing options in organizational quality analysis. After determining the main options, appropriate criteria and sub-criteria were selected under the main study area (water and wastewater resources management). In the next step, a "Multiple-Criteria Decision-Making (MCDM) " method based on "Fuzzy Analytical Hierarchy Process (FAHP)" and "Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)" method was used to identify the option that creates the most cost. The results show that the Appraisal cost option has the most significant impact on the quality cost in the water and wastewater management (37%), and other quality cost options include external failure (29%), internal failure (22%), and preventive (12%) are in the following ranks.

Introduction

The issue of global warming and its environmental effects on polar ice caps and depletion of water resources has made the issue of access to fresh water in the world an essential concern for policymakers in this field[1–3]. Furthermore, this has created competitive markets for the freshwater supply[4, 5].

Companies face various production costs in today's competitive market and must use appropriate strategies to profit and gain more market share[6]. Quality assurance for services and products has costs that the organization must bear to ensure customer satisfaction, maintain its customers, and expand its chances of living in the market[7, 8]. Recognizing the most crucial factor that creates the Cost of Quality (COQ) and providing appropriate solutions to minimize it helps companies increase economic efficiency and ultimately more profit[9]. Quality costs try to replace quality from scratch Production to prevent the creation of the poor quality product (improper service)[10]. In short, the quality costing system provides the necessary platforms for better products at a lower cost[11]. Quality costs are also costs that are not definitive and are hidden in other costs.

Internal and external failure costs, evaluation, and prevention are the determinants of COQ[12]. The company must consider the quality indicators to produce the service satisfied with the customer and has a good sale[13]. Therefore, given these critical factors, cost-making options must be considered. Identify the quality and select the option that creates the most cost, to minimize them[14]. Finding the most critical factor among the influential factors is another problem that decision-makers face[15]; Because in most service and production units, there is no purposeful plan to evaluate these costs, and the quality

cost is hidden in most other costs and can not be calculated accurately[16]. Therefore, the essential option for cost reduction should be selected according to the essential factors for the organization and quality cost options[17].

Problems of selection and evaluation of options in a situation where the decision-maker is faced with multiple options and criteria are one of the strategic issues that are solved using multi-criteria decision models[18]. In classic multi-criteria decision-making methods (MCDM), the utility and weight of the criteria are introduced as actual numbers, but factual data is not always available, and sometimes the decision-maker is faced with vague data[19, 20]. A combination of MCDM models and Fuzzy science are used[21, 22].

There are limited empirical and numerical researches that have been conducted on the Cost of Quality. Some of these researches are described below. He discussed the concept of quality management, management, and quality control in a study entitled Quality Engineering Systems. His results showed that the purpose of using a quality system is to reduce overall quality costs and achieve maximum profit[23]. Chopra and Garg examined the correlation between different quality cost classes in a study entitled Behavior Patterns of Quality Cost Classes. They believe that with increasing efforts towards assessment and prevention activities, non-compliance costs are reduced. In addition, there is a negative correlation between non-compliance costs and non-compliance costs[24]. Omar and Murgan studied an improved model for quality costing. Their result concluded that a reduction in failure costs leads to a decrease or no increase in non-compliance costs and that the traditional accounting approach is not sufficient for quality costing. Because the results largely depend on the cost of direct labor. Suppose the cost of direct labor is only 3% of the total cost of quality[25].

Nowadays, due to information and data uncertainty in some areas, the Fuzzy AHP method has been used by many researchers and has been accepted as an analysis with relatively accurate results[26]. This method has been used in recent studies in various fields such as travel[27], clothing[28], renewable energy[29], food industry[30], and management and supply[31], and efficient results have been extracted from these studies.

According to the contents, Fuzzy decision methods can be effective when uncertainty in the data and information. Due to the importance of freshwater supply and quality cost, the criteria are first weighed using this study's fuzzy Analytic Hierarchy Process (Fuzzy AHP). Then, the options are ranked using the Technique For Order Preferences By Similarity To Ideal Solution (TOPSIS) model, and the option that imposes the most costly to the water and wastewater industry is identified.

Principle Of Analysis

In different years, various models have been proposed to evaluate the cost of quality. What is essential in choosing a suitable model is that this selected model can well identify and explain the hidden costs in quality analysis. In this study, the "Prevention, Appraisal & Failure (PAF)" model, which is very popular[32,

33], has been used to evaluate the cost of quality. This model includes four main cost groups, as shown in Figure 1.

Juran showed an inverse relationship between "prevention and appraisal costs" and "failure costs" in the PAF model. Accordingly, more investment in both prevention and appraisal will reduce failure costs[34]. This inverse relationship indicates the optimal level of quality and is the basis of quality costing[35]. Figure 2 shows the quality cost chart in terms of quality levels.

- **Internal Failure Costs:** include defects identified in various stages before delivering the product or service to the customer by inspection or quality control units and action taken to eliminate it[36, 37]. In the present study, internal failure costs include water collection and treatment costs, water loss costs, preventive maintenance, failure analysis, wastewater recycling costs[38], water distribution and maintenance of good quality, treated effluent, and the cost of grading the quality of drinking water[39].
- **External Failure Costs:** These are costs that are not recognizable by the customer before use and are incurred after delivery and service to customers[40]. In the present study, external failure costs include sampling water quality from customers, customer dissatisfaction and complaints, and improving customer satisfaction[41].
- **Appraisal Costs:** These costs are used to determine the degree to which the characteristics of the products (or services) offered to match the quality characteristics of the reference[42, 43]. In the present study, these costs include evaluation costs of subcontractors (Operating contractor), raw water inspection and testing costs, production process inspection costs, final product inspection and testing costs, quality system audit costs, equipment control costs, Inspection and measurement costs, costs of checking the quality of water stored in tanks and costs of checking the quality of water delivered to subscribers[41, 44].
- **Preventive Costs:** These costs relate to activities spent to prevent defects and breakdowns in products (or services). Merely these costs reduce breakdowns and defects in manufactured products (or presented at different stages[45]. In the present study, these costs include quality planning costs, training costs[44], process design and control costs, and reporting costs[46].

Methodology

Considering that the primary purpose of this research is to evaluate the costs of quality (finding the option that has the highest cost) in the field of water resources management, the present study in the group of development studies with a descriptive approach (describing the conditions in the study Case) is placed.

Figure 3 provides a schematic of the conceptual model of the present study.

Due to the lack of a proper quality costing system, there is no accurate data on quality costs, and the available data is vague and inaccurate; Therefore, fuzzy logic has been used to decide and choose the

option that imposes the most cost. Four criteria of cost imposed (cost), final profit (profit), increase of credit (credit), and strategy focus time (strategy) and four options of internal failure costs, external failure costs, appraisal costs, and preventive costs are considered and for the opinion of ten experts decision-maker used.

The Analytic Hierarchy Process (AHP) is used to examine and weigh experts' opinions (usually 2 to 10 people) with paired questionnaires and, depending on the questioner's opinion and the review of incompatibility coefficients, the accuracy of the answers are evaluated. Here, weighting is done according to the appropriate incompatibility coefficient for each of the ten selected specialists. It should be noted that all calculations have been done in MATLAB software.

Model Description

In this research, first, the “Fuzzy Analytic Hierarchy Process (FAHP)” method is used to weight the criteria, and then the “Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)” is used to rank the options, which is briefly presented below.

Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP), known as one of the most common multi-criteria decision-making methods, was first proposed by Thomas Saati in 1980[47]. The application of this decision-making method is based on several different parameters and criteria (quantitative or qualitative). Since the classical AHP method is based on human resource judgment (decision-makers) and human judgment and perception are always associated with uncertainty, the present study uses the fuzzy AHP method[48]. The fuzzy AHP method is often used in uncertainty and amplitude of variation to rank a criterion[49]. Considering the choice of the fuzzy AHP method as the main algorithm, it is necessary to describe its steps. Various methods have been proposed in different references for fuzzy AHP[50], but since Chang's developed algorithm has more uncomplicated steps than others, this algorithm is used in the present study. In this method, fuzzy numbers are displayed as a two-dimensional array with format $(m_1 / m_2, m_2 / m_3)$ or a three-dimensional array with the format (m_1, m_2, m_3) . These values represent the smallest, most probable, and most significant possible values and the m_2 is between m_1 and m_3 [21]. In Figure 4, a triangular fuzzy number $\tilde{M} = (l, m, u)$ is presented. Also, the membership function of this fuzzy number is defined according to Equation 1, and the basic concepts of algebraic operations are used to follow the principles of fuzzy algebra[22].

$$\mu_{\tilde{M}}(x) = \begin{cases} 0 & x < l \text{ or } x > u \\ (x - l)/(m - l) & l \leq x \leq m \\ (x - u)/(m - u) & m \leq x \leq u \end{cases} \quad (1)$$

The AHP model is similar to human thinking and turns complex decisions into more straightforward problems, thus reducing the complexity of difficult decisions. The main steps of AHP are as follows:

- Organize the problem hierarchically: In the first stage, the problem is represented in the form of a tree in which, at its highest level, general objectives and the lowest level, options and between these two levels, criteria and sub-criteria are placed (Fig. 3).
- Development of a pairwise comparison matrix: The criteria are compared by decision-makers using pairwise comparisons of sub-criteria or options at a similar level and are represented in the form of pairwise comparison matrices according to the matrix of Equation 2[44].

$$\tilde{A} = [\tilde{a}_{i,j}] = \begin{pmatrix} \tilde{a}_{11} & \cdots & \tilde{a}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \cdots & \tilde{a}_{nn} \end{pmatrix} \quad (2)$$

- Calculate the internal pairwise matrices: Several methods have been developed to derive the weights of criteria from paired matrices, some of which are: eigenvector method, least logarithmic least squares method, least weighted squares method, and fuzzy programming method[22].
- Criteria ranking: The last step is to rank the options according to the final weight of each of them. The weights of each criterion are obtained by multiplying the internal weights of the sub-criteria of each level by each other and the sum of the final weights, and then the priorities are determined[48].

Technique For Order Preferences By Similarity To Ideal Solution (TOPSIS)

According to TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution), (m) options are evaluated by (n) indices, and each problem can be considered as a geometric system containing (m) points in n-dimensional space[21].

This model has the concept that "the selected option should have the shortest distance from the positive ideal solution (best possible case A_i^+) and the longest distance from the negative ideal solution (worst possible case A_i^-)".

This method is done in 6 steps as follows:

- Convert the initial decision matrix (D) to a non-scale matrix (ND) using the Euclidean norm[39].

- Calculation of unbalanced weight matrix (V) by multiplying the weighted unbalanced matrix (ND) by the index coefficient matrix (WJ).
- Determine the positive ideal solution (A_i^+) and the negative ideal solution (A_i^-) for all options according to Equation 3.

$$\begin{aligned} A^+ &= \left\{ \left(\text{MAX} V_{ij} \mid j \in J_1 \right), \left(\text{MAX} V_{ij} \mid j \in J_2 \right), i = 1, 2, \dots, n \right\} \\ A^- &= \left\{ \left(\text{MIN} V_{ij} \mid j \in J_1 \right), \left(\text{MAX} V_{ij} \mid j \in J_2 \right), i = 1, 2, \dots, n \right\} \end{aligned} \quad (3)$$

- Determine the Euclidean norm distance according to Equation 4.

$$\begin{aligned} d_i^+ &= \left(\sum_{j=1}^n \left(V_{ij} - v_j^+ \right)^2 \right)^{\frac{1}{2}}, (i = 1, 2, \dots, m) \\ d_i^- &= \left(\sum_{j=1}^n \left(V_{ij} - v_j^- \right)^2 \right)^{\frac{1}{2}}, (i = 1, 2, \dots, m) \end{aligned} \quad (4)$$

- Calculate the relative distance (A_i) to the ideal answer (C_i). In this case, the closer the option (A_i) is to the ideal solution, the closer its value (C_i) is to one. (Equation 5)

$$C_i = \frac{d_i^-}{d_i^- + d_i^+}, (i = 1, 2, \dots, n) \quad (5)$$

Ranking of options based on the relative distance (A_i) to the ideal answer (C_i) in descending or ascending order.

Fuzzy Logic

The foundation of fuzzy logic is based on the theory of fuzzy sets. This theory is a generalization of the classical theory of mathematical sets. In classical set theory, an element is either a member of the set or not (there is no third case)[48]. The membership of the elements follows a zero and one (binary) pattern. In contrast, fuzzy set theory introduces the concept of graded membership. In this way, an element can be

a member of a set to some extent (not wholly)[50]. The membership of the members of a set in fuzzy logic is determined by the function $\mu(x)$, where x represents a definite member, and μ is a fuzzy function that determines the degree of membership of x in the set and its value is between zero and one (Equation 6).

$$\tilde{A} = \{(x, \mu_A(x)) | x \in X\} \quad (6)$$

In other words, $\mu(x)$ maps x values with possible numerical values between zero and one. The function $\mu(x)$ may be a set of discrete or continuous values. When μ is a discrete value, only a small number of discrete values between zero and one are in the answer set; Whereas when the set of values μ is continuous, a continuous curve of decimal numbers between zero and one is formed in the set of fuzzy numbers[50]. An example of fuzzy numbers defined in the fuzzy Analytic Hierarchy Process (AHP) is presented in Table 1.

Table 1
Change the linguistic variable to the fuzzy triangular number

Linguistic Variable	Inverse Fuzzy Number	Fuzzy Triangular Number	Linguistic Variable
Absolutely less	(2/7, 1/3, 2/5)	(5/2, 3, 7/2)	Completely more
Much less	(1/3, 2/5, 1/2)	(2, 5/2, 3)	Much more
Less	(2/5, 1/2, 2/3)	(2/2, 2, 5/2)	More
Relatively less	(1/2, 2/3, 1)	(1, 3/2, 2)	Relatively more
A little less	(2/3, 1, 2)	(1/2, 1, 3/2)	A little more
Equal	(1, 1, 1)	(1, 1, 1)	Equal

Result And Discussion

Solving problems with fuzzy AHP and TOPSIS models require many calculations, which due to the existing limitations, only the final information and tables of indicators and results are reported. In this research, the opinions of 10 experts in water and wastewater resource management, according to the organizational chart of Figure 5, have been used.

Therefore first, the matrix of pairwise comparisons of criteria against each other was formed from the perspective of each expert, and the obtained data, which are linguistic variables, are converted into fuzzy numbers according to Table 1. Tables 2-4 provide three examples of a pairwise comparison matrix of expert decision-makers.

Table 2
Pairwise comparisons matrix of decision-maker- sample 1

	Cost Imposed	Final Profit	Increase of Credit	Strategy FocusTime
Cost Imposed	(1,1,1)	(1/2,2/3,1)	(1/3,2/5,1/2)	(1/2,1,3/2)
Final Profit	(1,3/2,2)	(1,1,1)	(2,5/2,3)	(1/2,1,3/2)
Increase of Credit	(2,5/2,3)	(1/3,2/5,1/2)	(1,1,1)	(2,5/2,3)
Strategy FocusTime	(2/3,1,2)	(2/3,1,2)	(1/3,2/5,1/2)	(1,1,1)

Table 3
Pairwise comparisons matrix of decision-maker- sample 2

	Cost Imposed	Final Profit	Increase of Credit	Strategy FocusTime
Cost Imposed	(1,1,1)	(1/2,2/3,1)	(2/7,1/3,2/5)	(1/2,2/3,1)
Final Profit	(1,3/2,2)	(1,1,1)	(1,3/2,2)	(1/2,1,3/2)
Increase of Credit	(5/2,3,7/2)	(1/2,2/3,1)	(1,1,1)	(3/2,2,5/2)
Strategy FocusTime	(1,3/2,2)	(2/3,1,2)	(2/5,1/2,2/3)	(1,1,1)

Table 4
Pairwise comparisons matrix of decision-maker- sample 3

	Cost Imposed	Final Profit	Increase of Credit	Strategy FocusTime
Cost Imposed	(1,1,1)	(1/2,1,2/3)	(1,1,1)	(2/3,1,2)
Final Profit	(2/3,1,2)	(1,1,1)	(1/2,1,3/2)	(1,1,1)
Increase of Credit	(1,1,1)	(2/3,1,2)	(1,1,1)	(2/3,1,2)
Strategy FocusTime	(1/2,1,3/2)	(1,1,1)	(1/2,1,3/2)	(1,1,1)

In each of the matrices, each of the cells above the main diagonal of a matrix indicates the degree of importance of the row elements relative to the column elements, and each of the lower cells of the main diagonal of a matrix indicates the degree of importance of the column elements to the row elements. They are the inverse of the value of the above main diagonal of a matrix. For each cell, the average weights determined by the experts were obtained using MATLAB software (Table 5), and finally, the weights of the criteria were obtained according to Figure 6.

Table 5
Matrix of average weights determined by decision-makers

	Cost Imposed	Final Profit	Increase of Credit	Strategy FocusTime
Cost Imposed	(1,1,1)	(0.5,0.777,1.166)	(0.539,0.577,0.633)	(0.555,0.888,1.5)
Final Profit	(0.888,1.333,2)	(1,1,1)	(1.166,1.666,2.166)	(0.666,1,1.333)
Increase of Credit	(1.833,2.166,2.5)	(0.5,0.688,1.166)	(1,1,1)	(1.388,1.833,2.5)
Strategy focustime	(0.722,1.166,1.833)	(0.777,1,1.666)	(0.411,0.633,0.888)	(1,1,1)

According to Figure 6, it can be seen that the effect of increasing credit has the greatest weight. In fact, from the point of view of experts, this criterion is the most essential in water and wastewater resources management.

In the following, the opinion of experts in the water and wastewater industry will be examined to examine the options. Since their analysis is a linguistic variable, fuzzy triangular numbers are used. In order to rank the options (with the model similar to fuzzy ideal options), defining fuzzy numbers are necessary. So fuzzy numbers, according to Table 6, have been used to convert experts' opinions about options.

Table 6
Convert a linguistic variable to fuzzy triangular numbers

Fuzzy Triangular number	Linguistic Variable
(0,0,1)	Very poor (VP)
(0,1,3)	Poor (P)
(1,3,5)	Relatively poor (RP)
(3,5,7)	Fair (F)
(5,7,9)	Relatively good (RG)
(7,9,10)	Good (G)
(9,10,10)	Very good (VG)

At this stage, the decision matrix was formed following the opinions of experts. Tables 7-9 show three examples of this matrix.

Table 7
Decision matrix-sample 1

	Cost Imposed	Final Profit	Increase of Credit	Strategy Focus Time
Internal Failure				
Waste and scrap costs	(7,9,10)	(0,1,3)	(0,0,1)	(0,1,3)
Repair and rework	(1,3,5)	(7,9,10)	(0,1,3)	(1,3,5)
Failure analysis	(0,0,1)	(9,9,10)	(7,9,10)	(0,1,3)
Improper maintenance of raw materials	(0,0,1)	(5,7,9)	(0,1,3)	(3,5,7)
External Failure				
Guarantee	(3,5,7)	(0,1,3)	(0,1,3)	(0,1,3)
Voice of the customer	(0,1,3)	(9,10,10)	(5,7,9)	(0,1,3)
Appraisal				
Evaluation of subcontractors	(0,1,3)	(9,10,10)	(9,10,10)	(9,10,10)
Inspection of inputs	(0,0,1)	(7,9,10)	(9,10,10)	(0,1,3)
Process inspection and testing	(1,3,5)	(9,10,10)	(9,10,10)	(0,0,1)
Inspection and testing of the final product	(0,0,1)	(7,9,10)	(5,7,9)	(0,0,1)
Establish an audit and quality system	(0,0,1)	(7,9,10)	(7,9,10)	(1,3,5)
Control of equipment inspection	(3,5,7)	(7,9,10)	(7,9,10)	(0,1,3)
Check the quality of inventory	(1,3,5)	(7,9,10)	(7,9,10)	(0,1,3)
Preventive				
Quality planning	(5,7,9)	(1,3,5)	(0,1,3)	(7,9,10)
Education	(0,0,1)	(7,9,10)	(0,1,3)	(3,5,7)

Table 8
Decision matrix-sample 2

	Cost Imposed	Final Profit	Increase of Credit	Strategy Focus Time
Internal Failure				
Waste and scrap costs	(7,9,10)	(0,1,3)	(0,0,1)	(0,1,3)
Repair and rework	(1,3,5)	(7,9,10)	(3,5,7)	(1,3,5)
Failure analysis	(0,0,1)	(9,10,10)	(9,10,10)	(3,5,7)
Improper maintenance of raw materials	(0,0,1)	(1,3,5)	(3,5,7)	(0,0,1)
External Failure				
Guarantee	(3,5,7)	(1,3,5)	(3,5,7)	(0,1,3)
Voice of the customer	(0,1,3)	(5,7,9)	(7,9,10)	(3,5,7)
Appraisal				
Evaluation of subcontractors	(0,1,3)	(9,10,10)	(9,10,10)	(3,5,7)
Inspection of inputs	(0,0,1)	(9,10,10)	(9,10,10)	(1,3,5)
Process inspection and testing	(1,3,5)	(9,10,10)	(9,10,10)	(0,1,3)
Inspection and testing of the final product	(0,0,1)	(9,10,10)	(9,10,10)	(0,1,3)
Establish an audit and quality system	(0,0,1)	(9,10,10)	(9,10,10)	(0,1,3)
Control of equipment inspection	(3,5,7)	(7,9,10)	(9,10,10)	(0,1,3)
Check the quality of inventory	(1,3,5)	(5,7,9)	(7,9,10)	(1,3,5)
Preventive				
Quality planning	(5,7,9)	(0,1,3)	(1,3,5)	(0,1,3)
Education	(0,0,1)	(3,5,7)	(7,9,10)	(0,1,3)

Table 9
Decision matrix-sample 3

	Cost Imposed	Final Profit	Increase of Credit	Strategy Focus Time
Internal Failure				
Waste and scrap costs	(7,9,10)	(7,9,10)	(3,5,7)	(7,9,10)
Repair and rework	(1,3,5)	(9,10,10)	(5,7,9)	(7,9,10)
Failure analysis	(0,0,1)	(7,9,10)	(7,9,10)	(5,7,9)
Improper maintenance of raw materials	(0,0,1)	(7,9,10)	(1,3,5)	(0,1,3)
External Failure				
Guarantee	(3,5,7)	(9,10,10)	(7,9,10)	(3,5,7)
Voice of the customer	(0,1,3)	(3,5,7)	(7,9,10)	(3,5,7)
Appraisal				
Evaluation of subcontractors	(0,1,3)	(7,9,10)	(7,9,10)	(1,3,5)
Inspection of inputs	(0,0,1)	(9,10,10)	(7,9,10)	(1,3,5)
Process inspection and testing	(1,3,5)	(7,9,10)	(5,7,9)	(7,9,10)
Inspection and testing of the final product	(0,0,1)	(5,7,9)	(9,10,10)	(7,9,10)
Establish an audit and quality system	(0,0,1)	(7,9,10)	(9,10,10)	(7,9,10)
Control of equipment inspection	(3,5,7)	(3,5,7)	(3,5,7)	(0,1,3)
Check the quality of inventory	(1,3,5)	(7,9,10)	(7,9,10)	(7,9,10)
Preventive				
Quality planning	(5,7,9)	(0,1,3)	(5,7,9)	(7,9,10)
Education	(0,0,1)	(5,7,9)	(5,7,9)	(7,9,10)

In the next step, the average weights determined by the decision-makers are calculated. Two examples of them are presented according to Tables 10-12.

Table 10
Determined average weights- sample 1

	Cost Imposed	Final Profit	Increase of Credit	Strategy Focus Time
Internal Failure	(2,3,4.25)	(5.25,6.75,8)	(1.75,2.75,4.25)	(1,2.5,4.5)
External Failure	(1.5,3,5)	(4.5,5.5,6.5)	(2.5,4,6)	(0,1,3)
Appraisal	(0.71,1.71,3.28)	(7.57,9.14,10)	(7.57,9.14,9.85)	(1.42,2.28,3.71)
Preventive	(2.5,3.5,5)	(4,6,7.5)	(0,1,3)	(5,7,8.5)

Table 11
Determined average weights - sample 2

	Cost Imposed	Final Profit	Increase of Credit	Strategy Focus Time
Internal Failure	(2,3,4.25)	(4.75,6.25,6.5)	(3.25,4.5,5.57)	(1,2.25,4)
External Failure	(1.5,3,5)	(3,5,7)	(5,7,8.5)	(1.5,3,5)
Appraisal	(0.71,1.71,3.28)	(8.14,9.42,9.85)	(8.71,9.85,10)	(0.71,2.14,4.14)
Preventive	(2.5,3.5,5)	(1.5,3,5)	(4,6,7.5)	(0,1,3)

Table 12
Determined average weights - sample 3

	Cost Imposed	Final Profit	Increase of Credit	Strategy Focus Time
Internal Failure	(2,3,4.25)	(7.5,9.25,10)	(4,6,7.75)	(4.75,6.5,8)
External Failure	(1.5,3,5)	(6,7.5,8.5)	(7,9,10)	(3,5,7)
Appraisal	(0.71,1.71,3.28)	(6.42,8.28,9.42)	(6.71,8.42,9.42)	(4.28,6.14,7.57)
Preventive	(2.5,3.5,5)	(2.5,4,6)	(5,7,9)	(7,9,10)

In the following, considering that the opinion of every ten experts is considered equal, their average opinion is presented in Table 13. The two criteria of Cost Imposed and strategy focus time are cost and are considered negative. The two criteria of Final Profit and increase of credit are profit and are considered positive.

Table 13
Final Matrix

	Cost Imposed	Final Profit	Increase of Credit	Strategy Focus Time
Internal Failure	(2,3,4.25)	(5.83,7.41,8.5)	(3,4.41,5.91)	(2.25,3.75,5.5)
External Failure	(1.5,3,5)	(4.5,6,7.33)	(4.83,6.66,8.16)	(1.5,3,5)
Appraisal	(0.71,1.71,3.28)	(7.83,9,9.76)	(7.66,9.14,9.76)	(2.14,3.52,5.14)
Preventive	(2.5,3.5,5)	(2.66,4.33,6.16)	(3,4.66,6.5)	(4,5.66,7.16)
Final	-0.1479	0.2965	0.3401	-0.2155

The final results presented for the main research criteria in Table 13 are the same as the final weights calculated in Figure 6. The importance of credit is indicated in the results of this table. Finally, by analyzing this data in MATLAB software, the ranking of options is obtained according to Figure 7.

The results of Figure 7 show that the most influential role in the cost of quality in water and wastewater resource management is related to the Appraisal option. This issue can be related to several parameters that play a role in the field of evaluation. Therefore, the Appraisal cost is the most crucial parameter in water resources management to improve the COQ.

Conclusions

Achieving quality costs is one of the significant problems in various industries and areas of management, especially water resources and wastewater management. Annually, a lot of time and money is spent on estimating the cost of quality of water resources and wastewater treatment, and there is no comprehensive information on the option that imposes the most cost in the field of quality analysis.

In the present study, in order to estimate the quality costs in the field of water and wastewater resources management and identify the option that creates the most cost, in the first step, the "Prevention, Appraisal, and Failure (PAF)" model was used to select cost-imposing options in organizational quality analysis. After determining the main options, appropriate criteria and sub-criteria were selected under the main study area (water and wastewater resources management). In the next step, a "Multiple-Criteria Decision-Making (MCDM) "method based on "Fuzzy Analytical Hierarchy Process (FAHP)" and "Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)" methods were used to identify the option that creates the most cost.

In this regard, the main areas of cost imposition (decision options) were selected under the headings ((Preventive Costs, Appraisal Costs, Internal Failure Costs, and External Failure Costs)) and the main criteria were selected as ((Cost Imposed, Final Profit, Increase of Credit and Strategy Focus Time)).

Finally, the outlines of the results are presented as follows:

- The highest cost of quality in the water and wastewater industry and its management are related to "Appraisal Costs" and account for 36.55% of total costs.
- The lowest cost of quality in the water and wastewater industry is related to "Preventive Costs" and accounts for only 12.18% of the total cost.
- Areas " External Failure Costs " and " Internal Failure Costs " are in second and third place with 28.98 and 22.30 percent of the total cost.

Quality costs account for a significant percentage of industry costs, while most managers and experts do not pay attention. This increases the cost of quality in the "Appraisal and External Failure "areas. With more emphasis on investing in preventative activities such as staff training, careful design of management charts, and troubleshooting of monitoring systems, in addition to reducing the cost of error and producing a defective product, the appraisal costs are also reduced.

Declarations

-Ethical Approval

- 1) This material is the authors' own original work, which has not been previously published elsewhere.
- 2) The paper is not currently being considered for publication elsewhere.
- 3) The paper reflects the authors' own research and analysis in a truthful and complete manner.
- 4) The paper properly credits the meaningful contributions of co-authors and co-researchers.
- 5) The results are appropriately placed in the context of prior and existing research.
- 6) All sources used are properly disclosed (correct citation). Literally copying of text must be indicated as such by using quotation marks and giving proper reference.
- 7) All authors have been personally and actively involved in substantial work leading to the paper, and will take public responsibility for its content.

-Consent to Participate

Not applicable

-Consent to Publish

The Authors hereby consent to the publication of the Work in the journal of water resource management

-Authors Contributions

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-Competing Interests

Not applicable

-Availability of data and materials

All data, models, and code generated or used during the study appear in the submitted article.

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Figures

Figure 1

Classification of quality costs in the PAF model

Figure 2

Quality cost chart according to quality levels in the PAF model

Figure 3

The conceptual model of the present study

Figure 4

The triangular fuzzy number diagram

Figure 5

The organizational chart of water and wastewater resource management based on the PAF model

Figure 6

The weight of the criteria obtained by the method of FAHP

Figure 7

Final ranking of quality cost options

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