An Integrated SERVQUAL, Fuzzy AHP, IPA, FMEA Framework for Prioritizing Service Quality Improvements in Public Water Utilities

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**Abstract*.*** This study aims to evaluate and improve the service quality of Regional Drinking Water Company (PDAM) through an integrated multi-methodology approach. This study combines the SERVQUAL method to identify the gap between customer expectations and perceptions, Fuzzy Analytic Hierarchy Process (Fuzzy AHP) to determine the priority weights of service attributes under conditions of uncertainty, Importance-Performance Analysis (IPA) to map the level of urgency and performance of each attribute, and Failure Mode and Effect Analysis (FMEA) to assess the risk level of attributes that are prioritized for improvement. The results show that attributes RS3 (speed of payment service), A2 (competence of technicians in managing disturbances), T3 (adequate technology utilization), E3 (polite and empathetic attitude of officers), and A4 (performance of the water distribution system) are service features that should be immediately prioritized in the improvement strategy. The findings make an important contribution in providing a comprehensive and data-driven service quality evaluation framework for the water public service sector. Recommendations for improvement are directed towards digitizing processes, strengthening technical training, implementing real-time monitoring systems, and communication strategies that are adaptive to customer needs. This framework is expected to serve as a reference for continuous improvement in the face of dynamic needs and operational risks in the water sector.

**Keywords:** Service quality; SERVQUAL; Fuzzy AHP; FMEA; PDAM

# **INTRODUCTION**

In the current landscape of public services, water utilities play a pivotal role in ensuring equitable access to safe and reliable clean water for the community [1]. Establishing public trust in service providers fundamentally depends on the consistent delivery of high-quality services. In the context of clean water provision, service quality not only reflects the operational efficiency of the Regional Water Company (PDAM) but is also intrinsically linked to customer satisfaction, environmental stewardship, and the socio-economic development of the community. Service quality is therefore a critical determinant for sustaining customer satisfaction, enhancing public trust, and ensuring the long-term operational sustainability of the utility [2]. As expectations for professional water services continue to rise, customers increasingly emphasize aspects such as supply availability, responsiveness, and the courteousness of field staff [3]. Comprehensive evaluations of service quality enable water utilities to identify performance gaps, mitigate the risk of customer complaints, and enhance operational efficiency [4, 5]. Such evaluations, when conducted systematically and continuously, constitute a strategic imperative for determining improvement priorities, optimizing resource allocation, and strengthening competitiveness in the face of growing demands for public services [6]. In the context of rapid population growth and increasing water demand, prioritizing service quality assessment is essential to ensuring that public water utilities can deliver reliable, sustainable services that generate value for both the community and the organization.

However, employing each of these approaches in isolation presents inherent limitations, particularly in decision-making contexts involving multiple criteria under uncertainty. While each method offers distinct advantages, their standalone application has not yielded sufficiently accurate priority recommendations when uncertainty is present. Previous studies have attempted to integrate SERVQUAL, IPA, and FMEA to assess service quality [7-9]; however, no research to date has incorporated Fuzzy AHP into this framework. Fuzzy AHP offers a distinct advantage in determining attribute weights with greater precision by accommodating the subjectivity and ambiguity inherent in expert judgments [10]. To address this gap, the present study proposes an integrated evaluation framework that combines SERVQUAL, Fuzzy AHP, IPA, and FMEA to comprehensively assess and prioritize service quality improvements. This integration not only reinforces the customer-based measurement foundation but also facilitates strategic decision-making that is responsive to both risk and uncertainty.

To address this gap, this research developed an integrated evaluation framework that combines SERVQUAL, Fuzzy AHP, IPA, and FMEA approaches into one systematic evaluation flow. The framework includes: identification of service attributes and measurement of the gap between customer expectations and perceptions using SERVQUAL [11], weighting of attributes based on customer priority levels through Fuzzy AHP [12], mapping of attributes into importance-performance quadrants using IPA [13], and assessment of service failure risks using FMEA [9]. This research aims to apply the framework to a public water company to generate more comprehensive, uncertainty-responsive, and risk-based service improvement priorities, so as to support continuous service quality improvement.

# **METHODS**

# **Proposed Framework**

This study proposes an integrated framework for evaluating and prioritizing service quality improvements in public water utilities. As illustrated in Figure 1, the framework comprises five main stages, integrating SERVQUAL, Fuzzy AHP, Importance–Performance Analysis (IPA), and Failure Mode and Effects Analysis (FMEA) into a cohesive assessment process.

**FIGURE 1**. The Proposed Integrated Framework for Service Quality Improvement Using SERVQUAL, Fuzzy AHP, IPA, FMEA

**Identification of Service Quality Dimensions**

The initial stage entailed the identification of service dimensions and corresponding attributes pertinent to the operational context of the water utility company. This process was guided by the SERVQUAL framework, which conceptualizes service quality through five core dimensions: Tangibles, Reliability, Responsiveness, Assurance, and Empathy [14]. Each dimension was operationalized into a set of context-specific attributes reflective of the characteristics of water service delivery. The survey instrument was systematically structured into two sections: the first captured customer expectations, while the second measured their actual perceptions of the services provided.

**Gap Analysis Using SERVQUAL**

The second stage was designed to quantify the discrepancy between customer expectations and their perceptions of the service, utilizing the SERVQUAL gap score as defined in Equation (1):

(1)

This approach evaluates the extent to which actual service performance aligns with, exceeds, or falls short of customer expectations [15]. A positive gap value signifies that the service outperforms customer expectations, whereas a negative gap value reflects performance deficiencies requiring targeted improvement.

**Weighting Priorities Using Fuzzy AHP**

The third stage employed Fuzzy AHP to determine the relative priority weights of each attribute under conditions of uncertainty. This method integrates fuzzy set theory into the conventional AHP to address the inherent subjectivity and ambiguity in expert judgments [16]. Triangular fuzzy numbers (TFNs) are utilized to represent linguistic preferences, such as “moderately important” or “very important,” enabling a more nuanced and precise quantification of qualitative assessments.

The main steps include:

1. Constructing a fuzzy pairwise comparison matrix based on expert judgment.
2. Aggregate TFN values from all experts for each comparison element.

(2)

1. Calculating the fuzzy synthetic value of each criterion:

(3)

1. Calculate the degree of dominance probability between criteria: (4)
2. Determine the unnormalized weight vector:

(5)

1. Normalize the weight vector to obtain the final weight:

(6)

The final weight of each attribute is used as the importance value in the IPA mapping stage

**Importance–Performance Mapping Using IPA**

The fourth stage employed the Importance–Performance Analysis (IPA) approach to position service attributes within four strategic quadrants. The horizontal axis represents performance levels derived from the SERVQUAL perception scores, while the vertical axis represents importance levels determined by the global weights obtained from Fuzzy AHP. Attributes exhibiting high importance but low performance are classified as top priorities for improvement. The global weight was computed using Equation (7):

(7)

**Risk Evaluation Using FMEA**

The final stage of the framework involved a risk assessment using the Failure Mode and Effects Analysis (FMEA) method. Each service attribute was evaluated based on three components: Severity (S), representing the magnitude of the impact; Occurrence (O), indicating the likelihood of the failure occurring; and Detection (D),

reflecting the ability to identify the failure before it impacts [17]. These components were multiplied to calculate the Risk Priority Number (RPN), as expressed in Equation (8):

(8)

A higher RPN value indicates a greater priority for corrective action. This approach enables organizations to implement proactive, risk-based service improvements that support continuous enhancement of service quality.

# **RESULT AND DISCUSSION**

This study evaluates the service quality of the PDAM from the customers’ perspective. Guided by the five SERVQUAL dimensions Tangibles, Reliability, Responsiveness, Assurance, and Empathy twenty specific service attributes were identified through literature review, field observations, and consultations with PDAM internal stakeholders, as presented in Table 1. These attributes served as the foundation for constructing the survey questionnaire, which was administered to 100 customer respondents.

**TABLE 1.** Service Quality Attributes of PDAM Based on SERVQUAL Dimensions

|  |  |
| --- | --- |
| **Code** | **Attribute Description** |
| **Tangible** | |
| T1 | The quality of water supplied by PDAM complies with established health standards. |
| T2 | Cleanliness and tidiness of the PDAM service office waiting area. |
| T3 | Utilization of adequate technology and equipment. |
| T4 | Clean and neat appearance of PDAM personnel. |
| **Reliability** | |
| RB1 | Ease of the registration process for new customers. |
| RB2 | Provision of detailed explanations by staff to customers. |
| RB3 | Staff adherence to the company’s standard operating procedures (SOPs). |
| RB4 | Employees’ ability to respond accurately to customer inquiries. |
| RB5 | Convenience for customers in making payments at payment counters. |
| **Responsiveness** | |
| RS1 | Promptness and responsiveness of employees in administering new customer services. |
| RS2 | Responsiveness of employees in addressing customer complaints. |
| RS3 | Promptness and responsiveness of employees in processing bill payments. |
| RS4 | Timely and accurate delivery of information related to services and repairs to customers. |
| **Assurance** | |
| A1 | Friendliness and politeness of complaint-receiving staff in service delivery. |
| A2 | Technical staff competence in resolving operational disruptions. |
| A3 | Employees’ comprehensive skills and knowledge relevant to their roles. |
| A4 | Assurance of the quality, quantity, and continuity of clean water supply to customers. |
| **Empathy** | |
| E1 | Sensitivity of complaint-handling staff to customers’ information needs. |
| E2 | Employees’ attentiveness to listening to customer needs. |
| E3 | Politeness and sincerity of employees in serving customers. |

An initial assessment of service quality was carried out using the SERVQUAL gap analysis, which compares customer perception scores with expectation scores for each service attribute. As shown in Table 2, most attributes recorded positive gap values, indicating that customers generally evaluated PDAM services favourably. However, seven attributes exhibited negative gaps, reflecting performance shortfalls in specific areas. The largest negative gap was observed in the cleanliness and tidiness of the service office waiting room (T2) at –0.40, followed by the ability of staff to provide detailed explanations to customers (RB2) at –0.33, and the promptness of new customer administration services (RS1) at –0.33. Other attributes, including the use of adequate technology and equipment (T3), the provision of timely and accurate service and repair information (RS4), convenience of payment at service counters (RB5), and employees’ attentiveness to customer needs (E2), also recorded negative gap values, albeit to a lesser extent. These results highlight that while the overall service quality is perceived positively, there remain critical areas requiring priority improvement, particularly in relation to physical facilities, administrative service speed, and the effectiveness of information delivery.

**TABLE 2.** Gap Analysis Results

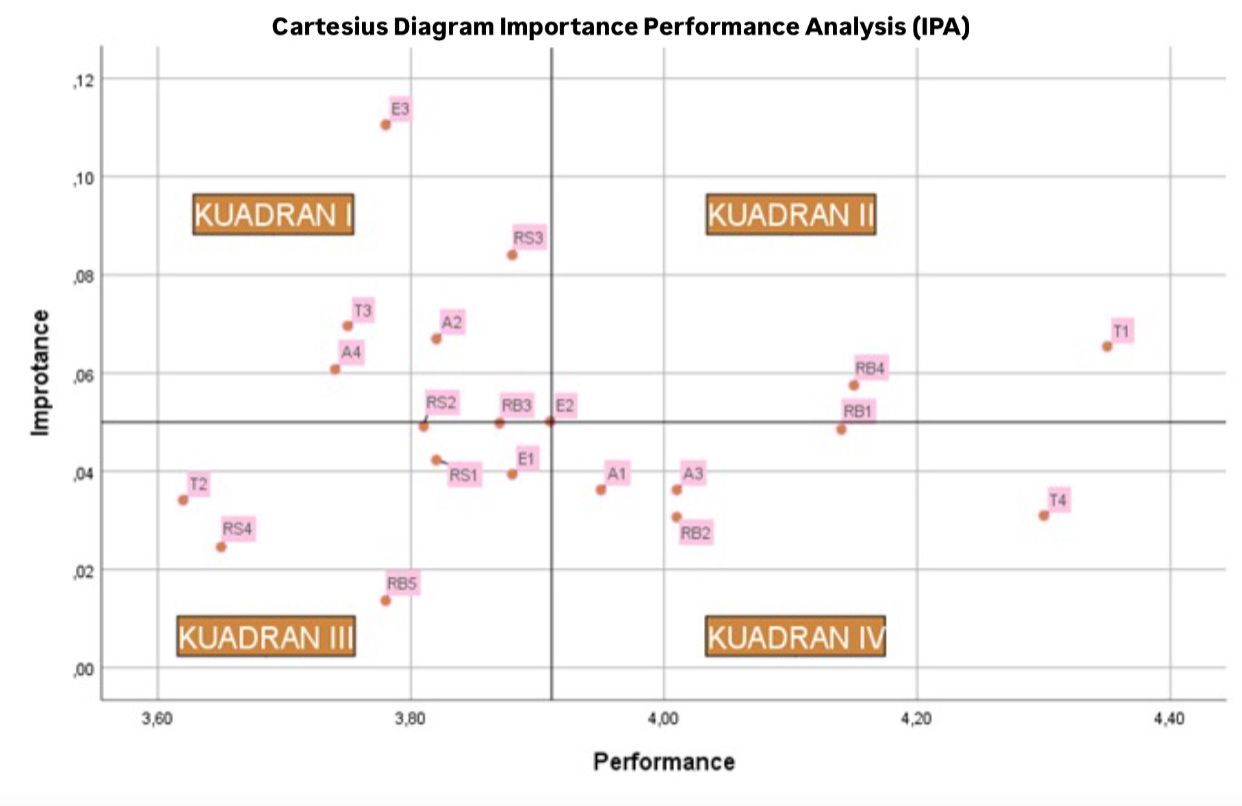
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Dimension** | **Attribute Code** | **Perception Score** | **Expectation Score** | **Gap** |
| Tangible | T1 | 4,35 | 4,04 | 0,31 |
| T2 | 3,62 | 4,02 | -0,4 |
| T3 | 3,75 | 3,95 | -0,2 |
| T4 | 4,3 | 3,85 | 0,45 |
| Reliability | RB1 | 4,14 | 3,72 | 0,42 |
| RB2 | 4,01 | 4,34 | -0,33 |
| RB3 | 3,87 | 3,59 | 0,28 |
| RB4 | 4,15 | 3,8 | 0,35 |
| RB5 | 3,78 | 3,94 | -0,16 |
| Responsiveness | RS1 | 3,82 | 4,15 | -0,33 |
| RS2 | 3,81 | 3,94 | -0,13 |
| RS3 | 3,88 | 3,75 | 0,13 |
| RS4 | 3,65 | 3,79 | -0,14 |
| Assurance | A1 | 3,95 | 3,73 | 0,22 |
| A2 | 3,82 | 3,69 | 0,13 |
| A3 | 4,01 | 3,85 | 0,16 |
| A4 | 3,74 | 3,6 | 0,14 |
| Empathy | E1 | 3,88 | 3,7 | 0,18 |
| E2 | 3,91 | 4,06 | -0,15 |
| E3 | 3,78 | 3,62 | 0,16 |

The subsequent stage involved weighting the priority of service attributes using Fuzzy AHP. The results of the calculation are presented in Table 3. The attribute “politeness and sincerity of employees” (E3) obtained the highest global weight of 0.110, reaffirming that the empathy dimension is the most influential factor in fostering customer satisfaction and loyalty. This was followed by “speed of payment services” (RS3) with a weight of 0.084, and “use of adequate technology and equipment” (T3) with a weight of 0.069. These findings indicate that, in addition to employee demeanour, both service process speed and technological support are critical in enhancing service quality. Conversely, “ease of payment at the counter” (RB5) recorded the lowest global weight at 0.013, signifying a relatively minimal contribution to the overall perception of service quality. These weight differentials formed the basis for mapping service improvement priorities in the IPA stage.

**TABLE 3.** Weight assessment for each indicator

|  |  |  |
| --- | --- | --- |
| **Dimension** | **Attribute** | **Global Weight** |
| Tangible | T1 | 0,065 |
| T2 | 0,034 |
| T3 | 0,069 |
| T4 | 0,030 |
| Reliability | RB1 | 0,048 |
| RB2 | 0,030 |
| RB3 | 0,049 |
| RB4 | 0,057 |
| RB5 | 0,013 |
| Responsiveness | RS1 | 0,042 |
| RS2 | 0,049 |
| RS3 | 0,084 |
| RS4 | 0,024 |
| Assurance | A1 | 0,036 |
| A2 | 0,066 |
| A3 | 0,036 |
| A4 | 0,060 |
| Empathy | E1 | 0,039 |
| E2 | 0,050 |
| E3 | 0,110 |

The integration of Fuzzy AHP weights with SERVQUAL perception scores produced a strategic map positioning service attributes within the four IPA quadrants, as illustrated in Figure 2. The mapping revealed that five attributes fell into Quadrant I (High Importance – Low Performance), namely politeness and sincerity of employees (E3), use of adequate technology and equipment (T3), speed of payment services (RS3), technical skills in handling operational disruptions (A2), and reliability of the quality and continuity of clean water supply (A4). Attributes in this quadrant represent the highest priority for improvement due to their high importance but suboptimal performance [18]. Strategic emphasis on these areas is expected to generate substantial and sustainable improvements in customer satisfaction.



**FIGURE 2.** Mapping of PDAM Service Attributes Based on Importance–Performance Analysis (IPA)

The FMEA assessment of the five priority attributes, as summarized in Table 4, produced Risk Priority Number (RPN) values indicating the relative urgency for improvement. The “speed of payment services” (RS3) recorded the highest RPN of 240, underscoring the need to modernize the payment system through process digitalization, queue time reduction, and optimization of frontline staff roles. The “technical skills of officers” (A2) obtained an RPN of 216, highlighting the necessity for technical capacity enhancement through troubleshooting training and fault simulation exercises. Both the “use of adequate technology and equipment” (T3) and the “politeness and sincerity of employees” (E3) registered an RPN of 210, warranting interventions such as infrastructure modernization via SCADA implementation and reinforcement of service excellence training programs. Meanwhile, the “reliability of the water distribution system” (A4) achieved an RPN of 150, which still merits attention through network inspection initiatives, distribution backup systems, and periodic customer satisfaction evaluations.

**TABLE 4.** Calculation of Risk Priority Number (RPN) for Critical Service Attributes

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| No | Atribut | Sev | Occ | Det | RPN | Rank |
| 1 | T3 | 7 | 5 | 6 | 210 | 3 |
| 2 | RS3 | 8 | 6 | 5 | 240 | 1 |
| 3 | A2 | 9 | 4 | 6 | 216 | 2 |
| 4 | A4 | 10 | 3 | 5 | 150 | 5 |
| 5 | E3 | 6 | 5 | 7 | 210 | 4 |

# **CONCLUSIONS**

This study integrated SERVQUAL, Fuzzy AHP, Importance–Performance Analysis (IPA), and Failure Mode and Effect Analysis (FMEA) into a unified framework to comprehensively evaluate and enhance the service quality of PDAM. The analysis identified five priority attributes requiring immediate improvement: speed of payment services (RS3), technical competence of staff (A2), adequacy of operational technology (T3), politeness and empathy of staff (E3), and reliability of the water distribution system (A4). Managerial implications include the digitalization of payment processes, enhancement of technical and customer service competencies through targeted training, implementation of real-time monitoring systems, and development of responsive communication strategies. The proposed framework contributes to both theory and practice by offering a data-driven, risk-based approach for prioritizing service quality improvements in the public water utility sector. Furthermore, the framework is adaptable for application in other PDAMs and similar service-oriented organizations, supporting the attainment of Sustainable Development Goals (SDG) 6 on clean water and sanitation.

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