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Integration of fuzzy SERVQUAL and TRIZ models in service quality method

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ABSTRACT

Quality service in the field of Occupational Safety and Health (OSH) training is an important factor in supporting effective learning and participant success in the certification process. This study evaluates the quality of OSH training services and proposes solutions to enhance participant satisfaction using PT FTI as a case study. Fuzzy SERVQUAL and TRIZ methodologies were combined to identify inconsistencies between participants' expectations and perceptions across five dimensions of service quality: physical form, reliability, responsiveness, assurance, and empathy. The results showed three attributes with the highest negative gaps: lack of even-handed attention, unclear information delivery, and perceived irrelevance of training materials. Based on TRIZ principles, the study proposes innovative solutions, such as hybrid training (online and offline), increased information transparency, separation of knowledge and skills evaluation, and rearranging materials to make them more contextual. The combined use of fuzzy SERVQUAL and TRIZ offers a systematic and effective strategy for analyzing and improving training quality.

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1. INTRODUCTION

The service sector's growth in Indonesia has led to an increase in the need for professional and advanced training services, including Occupational Safety and Health (OSH) [1]. In the midst of increasingly intense industrial competition, training service providers are required to not only comply with applicable regulatory provisions but also increase competitiveness through the provision of quality services. According to data from the Ministry of Manpower, the number of officially registered Occupational Safety and Health Service Companies will reach 1,151 by the end of 2023. This condition demonstrates the increasingly dynamic market and the increasing level of competition in the training services sector.

Participant satisfaction is one of the factors that determine the sustainability and credibility of OSH training institutions in increasingly competitive conditions [2]. Therefore, service quality must be a major concern in maintaining competitiveness. However, assessing the quality of training services is not easy because the characteristics of the service are intangible; therefore, it is difficult to measure the quality directly [3]. This condition requires an evaluation process that considers various points of view, both from the organiser and the training participants, so that the quality of the services obtained is more comprehensive.

In practice, many training institutions have not implemented a structured evaluation system and supported optimal data utilisation [4]. Consequently, service improvement efforts are often only conducted in response to problems that arise, without being based on a systematic or innovation-oriented approach [5]. In a competitive service industry, the ability of service providers to meet and even exceed participants'

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expectations is an important factor in creating customer satisfaction, which is the main goal of any service provider organisation [6].

The SERVQUAL model is one of the widely adopted frameworks for evaluating service quality in the context of training and education, which measures the gap between customer expectations and perceptions in five dimensions: tangibles, reliability, responsiveness, assurance, and empathy [7]. Various studies have shown that the five dimensions of SERVQUAL have a real influence on the level of participant satisfaction and the effectiveness of learning outcomes, both in professional training programmes and in higher education environments [8]. This influence is increasingly important in the implementation of online-based and blended learning, where the quality of the interaction between the organisers and participants greatly determines the learning experience. In these conditions, the dimensions of assurance and empathy receive greater attention because they are related to the organiser's ability to build trust, provide a sense of security, and understand the needs and characteristics of participants during the learning process.

These dimensions have been shown to be foster trust, engagement, and confidence among learners [8], [9]. The quality of the digital platform, learning materials, and user interface are tangible elements that have been shown to play an important role in shaping participants' perceptions of the quality of service [10]. Many studies have identified responsiveness as a key factor influencing satisfaction in the online training context. These findings agree with the SERVQUAL dimension, which underscores the importance of responsiveness in increasing satisfaction levels in the online education environment [9].

This issue has an impact on participant satisfaction, learning process effectiveness, and perceived credibility of professional certification. In contrast to various service sectors that have been studied, ineffective occupational safety and health (OSH) training can produce two main outcomes. First, it can lead to dissatisfaction among participants. In addition, errors in the implementation of safety procedures by participants after attending the training can increase the risk of work accidents in the operational environment. Therefore, training quality is a factor that greatly determines the effectiveness of the learning process. Training programmes supported by comprehensive materials, instructors with adequate competence, and a conducive learning environment have been proven to increase the level of participant satisfaction [8]. This satisfaction not only reflects the quality of the services received but also contributes to increased learning outcomes, including understanding of concepts, knowledge retention, and the ability to apply skills in the workplace [10].

The credibility of K3 certification is also influenced by the quality of the training implementation. Compliance with applicable standards and the professionalism of instructors in delivering materials are important factors that strengthen participants' confidence in the obtained certification [9], [11]. Various studies have shown that quality training services not only have a positive impact on short-term learning outcomes but also increase participants' loyalty to training providers. This impact ultimately strengthens participants' perception of the value and benefits of K3 certification as a provision in supporting performance and safety in the work environment [12].

Despite its various advantages, online-based professional training still faces several challenges that can affect the quality of service. Frequently encountered obstacles include technical problems, limited interaction with instructors, and low participant involvement during the learning process [10]. In addition, the limitations of digital infrastructure and the lack of optimal interactive learning environments also make the learning experience less effective [11], [13]. However, the submission of unclear information about certification procedures and evaluation results can reduce participants' confidence in the training programme's credibility and effectiveness [14]. Therefore, addressing these shortcomings is essential to increase the satisfaction, trust, and effectiveness of learning in online K3 training programmes.

An in-depth examination of the SERVQUAL dimensions demonstrates that responsiveness, reassurance, and empathy are essential in the context of digital training platforms. Responsiveness is defined as the speed with which a service provider handles questions and concerns of participants. This encourages a learning environment that supports and strengthens the confidence of participants [15], [16]. Assurance, which includes staff competence, courtesy, and credibility, increases participant confidence and perception of the training provider's reliability [16]. Empathy, which reflects the provider's ability to understand and accommodate the individual needs of participants, further strengthens the participant-provider relationship and contributes positively to satisfaction and trust [9], [12].

Recent trends between 2019 and 2025 show a substantial evolution in service quality management in the field of training and education, particularly influenced by the strengthening of OSRs and certification requirements in the labour sector. The development of digital technology has encouraged the application of more personalised learning through the adjustment of training materials according to the needs of participants to improve the learning experience and participant satisfaction [17], [18]. On the other hand, the use of data analytics is increasingly used as a basis for continuous evaluation and improvement of services,

so that training institutions can more responsively identify shortcomings and make adjustments [19], [20]. In addition to mastering technical competencies, developing nontechnical skills (soft skills) is now also an important part of training implementation to increase participants' work readiness [18], [21]. These changes have been accelerated since the COVID-19 pandemic, which has encouraged training institutions to strengthen the quality of online learning services, especially in relation to digital literacy, ease of use, and reliability of learning platforms [22], [23].

PT FTI is one of the officially registered K3 (Occupational Safety and Health) training providers and has been in operation since 2020. Although the institute has made efforts to diversify its participant base, approximately 80% of participants still come from the internal environment of the Faculty of Industrial Technology, Universitas Muslim Indonesia, which shows limited market penetration. Additionally, while online training offers advantages in terms of efficiency and cost-effectiveness, it is often considered less effective for delivering practical, field-based learning components [24]. Expert training programmes at PT FTI are currently conducted online, without face-to-face instruction. The absence of a structured feedback and evaluation system has also been identified as a factor causing stagnation of service quality and limited innovation [25].

Various methodological approaches, including the conventional SERVQUAL model, have been applied to evaluate service quality. However, traditional SERVQUAL has limitations in capturing the linguistic ambiguity and subjective perceptions inherent in customer evaluations. To overcome these limitations, the fuzzy SERVQUAL method was developed to accommodate uncertainty and ambiguity in participant assessments [15]. In addition, TRIZ offers a systematic and innovation-oriented framework for developing structured solutions to service-related problems [26]. This approach is particularly relevant for OSH training services, where improvements must balance the accessibility of training and the development of practical safety competencies. The integration of Fuzzy SERVQUAL and TRIZ has been implemented in the public service sector, such as hospitals and clinics [27]. However, studies that apply this approach to OSH training services are still limited. This study proposes the integration of fuzzy SERVQUAL and TRIZ as a framework for evaluation and service improvement that not only reveals quality gaps but also produces more systematic and applicable alternative solutions, especially for the implementation of online and hybrid-based OSH training.

Based on these problems, this study evaluates the quality of K3 training services at PT FTI through the integration of fuzzy SERVQUAL and TRIZ. This approach is used to identify gaps between participants' expectations and perceptions and translate the evaluation results into recommendations for improvement. Unlike previous research that generally stops at the service quality measurement stage, this study combines the evaluation process and solution formulation in one analytical framework. The findings of this study expand the application of fuzzy SERVQUAL and TRIZ to K3 training services and offer a more systematic service quality improvement model for decision-making

2. RELATED WORK

Research on improving service quality has been conducted in health, transportation, education, and training sectors. An inductive approach was used through a literature review of relevant studies from the past five years to develop the theoretical basis and describe the originality and urgency of this research. This literature review aims to identify methodological trends, assess the contribution of previous findings, and reveal limitations that leave room for further study. Table 1 presents a summary of the comparison between previous studies and this research to clearly highlight the identified research gap.

This research is one of the new approaches to applying fuzzy-SERVQUAL and TRIZ, specifically in the OSH training sector. Using data on the discrepancy between customer perceptions and expectations, this study identifies the root of the problem and produces innovative, contextual service improvement solutions. This research is novel because it combines the application of fuzzy servqual and TRIZ, which have not been widely applied in the OSH training domain. Moreover, it uses TRIZ to produce solutions that are proactive and creative, not just reactive to survey results. Moreover, it emphasises designing training service quality based on actual customer data in the professional training service sector. Thus, this research is expected to contribute significantly to the development of strategies for improving the quality of systematic, user-oriented training services.

3. RESEARCH METHODS

This section describes the reasons for selecting specific approaches, methods, procedures, or techniques to identify, select, and analyse information to understand the research problem or project, while providing a basis for readers to assess the study's validity and reliability. This study employs a quantitative descriptive approach using the Fuzzy SERVQUAL method to evaluate and improve the quality of nationally recognised certification under OSH training services for participants in the General OSH Expert Certification Programme, referring to "*Ahli Kecemasan Keselamatan dan Kesihatan Pekerjaan Utama (AK3U)*". The fuzzy method is used to address uncertainty and linguistic subjectivity in

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Table 1. Analysis of research gaps

Author(s)	Method	Sector / Object	Key Findings	Research Gap
Nojavan *et al*. [28]	Fuzzy SERVQUAL integrated with Fuzzy AHP, TOPSIS, and DEA	Higher education institutions (HEIs)	A hybrid fuzzy SERVQUAL framework was proposed to evaluate service performance and rank educational institutions based on service quality dimensions.	Focuses on the performance evaluation and ranking of educational institutions; does not develop innovative service quality improvement strategies.
Mouhib *et al*. [29]	Fuzzy SERVQUAL	Industrial maintenance (Total Productive Maintenance implementation)	The success level of TPM implementation was evaluated, and key human factors influencing service quality were identified.	Limited to evaluating service gaps in industrial maintenance; does not integrate IBS methods.
Farshianabbasi *et al*. [30]	SERVQUAL + Fuzzy Kano	After-sales service in household appliance industry	Negative gaps between customer expectations and perceptions were identified, and service attributes were categorised using the Kano model.	Provides structured service attribute categorisation but produces relatively conventional improvement recommendations.
Shen [31]	Fuzzy Delphi Method + AHP based on SERVQUAL	Property management services	A service quality evaluation scale was developed to identify key service attributes valued by customers.	This study focuses on identifying service quality factors without proposing systematic innovation-based improvement solutions.
Boavida *et al*. [32]	TRIZ + Eco-Compass	Telecommunication infrastructure services	Demonstrated that TRIZ can generate innovative and sustainable solutions for organisational improvement.	Does not integrate customer perception-based service quality evaluation, such as that of SERVQUAL.
Dewi *et al*. [33]	SERVQUAL + TRIZ	Healthcare (hospital outpatient services)	Identified service gaps and applied TRIZ inventive principles to improve service efficiency and reduce waiting time.	Application limited to the healthcare sector; research on professional training services remains limited.
This Study	Fuzzy SERVQUAL + TRIZ	Occupational Safety and Health (OSH) training services	Identifies service quality gaps based on participant expectations and perceptions and develops innovative improvement strategies using TRIZ principles.	Addresses the limited application of the integrated fuzzy SERVQUAL and TRIZ methods in the OSH training sector.

assessing customer perceptions [34]. Meanwhile, the TRIZ is used to develop innovative solutions in service improvement, which works through stages or algorithms starting from problem formulation to contradiction identification [35].

Step 1: Primary data collection is conducted by distributing questionnaires to AK3U trainees at various stages of the training programme. This questionnaire was designed to assess participants' perceptions of the five service dimensions, namely, responsiveness, reliability, assurance, empathy, and physical evidence. To ensure the conceptual validity and reliability of the measurement instruments, the questionnaire items are adapted from SERVQUAL-based studies that have been previously validated in training and service quality evaluation. Table 3 (service quality attributes) in the results section presents a detailed list of questionnaire indicators used in this study. Direct

observation was also conducted to gain a deeper understanding of the interaction between participants and service providers. The respondents consisted of participants who had completed the training programme. Basic demographic information, including age, educational background, and work experience, was collected to provide a clearer sample profile.

Step 2: The second step involves transforming respondents' perceptions and expectations rankings into fuzzy representations to account for linguistic ambiguity and subjective variability in evaluating service performance. Perceptions and expectations were measured using a performance-based scale of 0–10, ranging from "very dissatisfied" to "very satisfied," and "very unimportant" to "very important," to maintain conceptual consistency for gap analysis and allow for a more sensitive representation of respondents' judgments. For example, a response categorised as "Satisfied" is represented by a triangular fuzzy number (6, 7, 8), reflecting the lower, middle, and upper bounds of the linguistic scale.

Each response was then classified into fuzzy sets, modelling the lower, modal, and upper bounds of the linguistic term as a TFN (Table 2). This procedure preserves uncertainty in respondents' judgments and ensures that the subsequent calculation of the perception–expectation gap accurately reflects differences between expected and experienced service quality

Table 2. Fuzzy set perception/expectation

The Universe of Speakers	Fuzzy set name	Domain	Range
0-10	Very dissatisfies/ important	0-2	0,1,2
0-10	dissatisfies/ important	2-4	2,3,4
0-10	Quite dissatisfies/ important	4-6	4,5,6
0-10	Satisfied/Important	6-8	6,7,8
0-10	Very Satisfied/Important	8-10	8,9,10

Step 3: The fuzzification process was applied to validate the scores given by the respondents for each attribute in the questionnaire. The fuzzy set values of all respondents were then obtained by calculating the average weight using the arithmetic mean method.

Step 4: After that, the defuzzification process is performed. This stage determines the degree of membership while producing defuzzification values. Defuzzification values are obtained by calculating the arithmetic mean of ai, bi, and ci.

$$d = \frac{ai + bi + c}{3} \quad (1)$$

where b = Upper limit value; a = Middle limit value; c = Lower limit value; bi = fuzzy average value at each level of importance; and n = number of respondents at that level.

Step 5: The discrepancy between perceptions and expectations, referred to as the Expectation-Perception Gap, is determined by the service dimension's defuzzied values. This provides greater insight into how well the service provider is meeting trainees' expectations across different aspects of service delivery.

Step 6: The quality of service is then analysed based on the discrepancy between respondents' perceptions and expectations.

$$Service\ Quality\ Score\ (S) = Perception\ Score(P) - Expectation\ Score(E) \quad (2)$$

Step 7: For attributes exhibiting the highest gap value (negative), a cause analysis employing TRIZ methodology was conducted. The following elements are encompassed in this stage:

a) The initial step in this process involves the identification of engineering parameters based on the 39 Engineering Parameters in the classical TRIZ framework proposed by Altshuller. These parameters were selected because of their suitability in representing the technical and operational characteristics of the service quality attributes identified in this study.
b) It is paramount to select the principles that appear most frequently or are most relevant to serve as the basis for improvement [36].

This transformation enables the representation of qualitative service quality issues as structured technical contradictions, enabling systematic and solution-oriented analysis using the TRIZ framework.

Step 8: The proposed solutions for enhancing service quality, which were developed based on the results of the gap analysis and TRIZ, included the following: improving communication processes, enhancing instructor competence, and strengthening online training facilities. Each recommendation is derived from a set of inventive principles that align with the unique characteristics of the problem and the company's available resources.

4. RESULTS AND DISCUSSION

Primary data were obtained through direct observation and interviews with training participants (service users) and service providers regarding complaints and obstacles that arose during the training. The identification results show that the service quality attributes are systematically classified into five SERVQUAL dimensions, namely, tangibles, reliability, responsiveness, assurance, and empathy. Table 3 shows the results of the identification of service quality attributes.

This study aims to determine the fuzzy set of respondents' responses for each questionnaire attribute

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Table 3. Service quality attribute identification in training implementation

Dimension	Code	Service Attribute	Source
Tangibles	Q1	The training materials have been carefully prepared and are relevant to the needs of the target group.	Rahmawati *et al.* [37]
	Q2	The training schedule is readily accessible and provides clear information.	Zygiaris *et al.* [38]
	Q3	Training equipment and materials provided	Supardi *et al.* [39]
	Q4	Readiness and availability of facilities throughout the training.	Faizah, *et al.* [40]
Reliability	Q5	Training materials are consistently delivered according to plan.	Ehsan *et al.* [41]
	Q6	All of the provided links are fully operational.	KhanMohammadi *et al.* [42]
	Q7	The Training Institute has earned a reputation for its credibility and reliability.	Putri and Rahmat [43]
	Q8	Reliability of staff in providing accurate and timely information.	Nguyen [44]
	Q9	The language is characterized by its comprehensibility, facilitating easy understanding.	Supardi *et al.* [39]
Responsiveness	Q10	The training organizers have demonstrated a prompt response to the expressed concerns of the participants.	Alam and Mezbah-ul-Islam [45]
	Q11	The staff's provision of information regarding training was characterized by a high degree of clarity.	Aldaarmi [46]
	Q12	The agency has a policy of giving due consideration to the suggestions and complaints of training participants.	Behdioglu and Arda [47]
Assurance	Q13	The instructors have sufficient credibility and knowledge.	Nyuyen [44]
	Q14	Participant data and evaluation results are stored and managed securely.	Putri and Rahmat [43]
	Q15	Participants will gain knowledge and skills through training activities.	Ghozal *et al.* [48]
Empathy	Q16	The training material is delivered in simple language that is easy for participants to understand.	Jing *et al.* [49]
	Q17	Organizers and participants establish good communication.	Lippitt *et al.* [50]
	Q18	All trainees receive identical service and communication without any exceptions	Hatipoglu and Koc [51]

expressed in linguistic variables. Perception and expectation were measured using a 0–10 performance-based scale, ranging from "very dissatisfied" to "very satisfied," and "very unimportant" to "very important," to maintain conceptual consistency for gap analysis and allow more sensitive representation of respondents' judgments. The SERVQUAL Fuzzy calculation calculates the difference between perception and expectation to assess the quality of AK3U certification training as follows:

Gap = Perception - Expectations

= 7.17–7.88 = -0.73

This example illustrates the defuzzification-based gap calculation. The use of the fuzzy approach is justified because it effectively captures subjective and imprecise evaluations, which are inherent in-service quality assessment, thereby improving the robustness of the analysis compared to conventional crisp methods.

The gap analysis results show that all values are below zero. This indicates that the services provided have not met the training participants' expectations, so improvements are needed to achieve optimal service quality. The attributes with the highest negative gap values in each SERVQUAL dimension were selected as priority problems (Table 4). These attributes were then translated into TRIZ parameters by defining the desired improvements (i.e., improving features) and potential trade-offs (i.e., worsening features), enabling their analysis using the TRIZ CM. Table 5 presents a contradiction mapping of the five main problematic attributes.

Table 4. Calculation of the gap between perceptions and expectations

SERVQUAL Dimensions	No	Defuzzification		Gap per Indicator Question	Rank	Gap per Aspect	Rank
		Perception	Expectations				
Empathy	Q16	6.98	7.82	-0.84	2	-0.82	1
	Q17	6.88	7.80	-0.92	3		
	Q18	7.17	7.88	-0.72	1		
Reliability	Q5	6.75	7.83	-1.08	5	-0.84	2
	Q6	7.02	7.90	-0.88	3		
	Q7	7.59	7.95	-0.36	1		
	Q8	6.87	7.75	-0.88	2		
	Q9	6.95	7.92	-0.97	4		
Assurance	Q13	7.15	7.85	-0.70	2	-0.85	3
	Q14	6.83	8.02	-1.19	3		
	Q15	7.15	7.82	-0.67	1		
Tangible	Q1	7.23	7.95	-0.73	1	-0.99	4
	Q2	6.72	7.87	-1.15	4		
	Q3	6.87	7.85	-0.98	2		
	Q4	6.85	7.95	-1.10	3		
Responsiveness	Q10	6.56	7.75	-1.19	2	-1.16	5
	Q11	6.84	7.80	-0.96	1		
	Q12	6.43	7.75	-1.33	3		

Table 5. The TRIZ contradiction matrix

Attributes	Improving Feature	Worsening Feature
It is imperative to allocate equal attention to both	Loss of information (24), extent of automation (38)	Device Complexity (36), Ease of Operation (33)
The institution has been proven trustworthy	Reliability (27)	Actual vs. Plan (28)
Possession of knowledge and the capacity to apply skills are essential for success in this field.	Information accuracy (39)	Extent of Automation (38)
Training materials are pertinent	Extent of Automation (38)	Ease of operation (33)
Clarity in staff information is paramount	Visibility (18)	Ease of operation (33)

Table 6 shows how each service attribute is mapped into the TRIZ parameters. The improving feature represents the expected service enhancement, whereas the worsening feature reflects the improvement's possible constraints. The service attributes with the highest negative gaps are first identified as priority problems and then translated into these parameters to form structured contradictions. The contradiction matrix is used to identify relevant inventive principles based on this mapping, which are subsequently interpreted into practical service improvement solutions. The following table summarises the application of TRIZ principles to solve each service attribute.

Through this approach, each proposed improvement is systematically prepared with reference to the priority of service gaps obtained from the SERVQUAL analysis and the problem-solving principles developed in TRIZ. The TRIZ approach transforms the results of problem identification into

Table 6. Application of inventive principles

Attributes	Inventive Principles	Solution
Provide equal attention	Asymmetry (4), Blessing in Disguise (22), Another Dimension (17), Dynamization (15), Intermediary (24)	Balanced interaction allocation, hybrid training, participant groups, varying methods, and additional modules
Trusted institution	Segmentation (1) and Blessing in Disguise (22)	Credibility audit: Transforming obstacles into opportunities
Knowledge and skills	Segmentation (1) and another dimension (17)	Modules tailored to expertise, online discussions, and multimedia
Relevant Training Materials	Intermediary (24), Dynamization (15)	visualisation of materials and regular updates
Clear staff information	Asymmetry (4)	visualising intuitive information

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alternative solutions that are more directed and innovative and can be applied to the training implementation process. By combining the results of the gap analysis and a systematic problem-solving framework, the resulting recommendations not only focus on improving the most critical aspects of the service but also provide the basis for the development of a service quality improvement strategy that is

Table 7. The following proposals are submitted for consideration as potential solutions to improve the effectiveness of hybrid training methodologies

Stages of the SOP	Implementation Strategy
Preparation before training	1. Before the training started, the participants were recorded and provided with information about the implementation schedule, technical requirements, and guidelines for using the online learning platform. 2. The organisers ensure that all online learning supporting infrastructure is available and functioning properly. This stage includes checking the stability of the internet connection, hardware and software readiness, and system compatibility during the training.
The following section addresses the training scheduling	1. It is important to develop a comprehensive and flexible training schedule to meet the diverse needs of participants while also considering the logistical constraints of the available infrastructure. 2. It is essential to carefully organize online and offline sessions and ensure that participants are aware of the training time and place.
The following text constitutes the introduction and orientation of the study.	1. The training schedule is systematically prepared by considering the needs of the participants, the flexibility of implementation time, and the availability of supporting facilities and infrastructure so that the learning process can run optimally. 2. The implementation of online and offline learning sessions is coordinated. To ensure a smooth training process, all information regarding the time, location, and implementation mechanism was conveyed to the participants before the activity began.
During online sessions	1. Instructors deliver learning materials through online platforms by utilising various methods, such as presentations, demonstrations, and interactive discussions, to encourage participants' active participation during the training process. 2. Face-to-face activities at the training site focus on practical learning through simulations and hands-on exercises. All activities are conducted while still complying with the provisions of occupational safety and health and applicable procedures.
Guidance and monitoring	1. During online learning, instructors monitor participants' participation, provide responses to questions asked, and provide assistance through communication features available on the learning platform. 2. In the face-to-face session, the instructor provides direct direction and guides the implementation of the practice so that the participants can understand and apply the training material well.
Evaluation and Examination	1. After the completion of the entire training series, an evaluation is conducted through questionnaires or online media to obtain feedback on the training quality and the experience of participants during the programme. 2. The implementation of the AK3U certification exam, both online and offline, is scheduled in accordance with the applicable certification provisions and standards.
Follow-up and Certification	1. After the evaluation or exam process is completed, the assessment results are submitted to the participants as feedback material. Follow-up in the form of advanced training or competency development programmes is prepared according to the evaluation results if necessary. 2. Certificate documents or proof of training completion are prepared in accordance with applicable regulations and then distributed to participants based on the company's procedures.

oriented to the participants' needs. The application of this approach is expected to support the creation of training services that are more responsive to change, sustainable, and of better quality.

Improvement recommendations are manifested in the form of a training implementation system design based on the concept of hybrid training and supported by the preparation of the SOP. This training model combines online and offline learning to reduce technical constraints, increase participant participation, and expand access to training programmes. The preparation of SOPs refers to the innovative principles obtained from the results of the contradiction analysis using TRIZ (Table 5). Furthermore, each principle is translated into operational steps that are in accordance with the training implementation needs, including increasing communication effectiveness, implementation flexibility, and strengthening interaction between instructors and participants. With this approach, the resulting SOPs reflect the systematic problem-solving process based on TRIZ and are designed to be easily implemented in the operation of OSH training services (Table 7).

The preparation of a hybrid learning-based training SOP that covers all stages, from preparation to the certification process, is designed to support the implementation of AK3U training that is more effective, flexible, and centred on the needs of participants. The combination of online and offline learning not only expands the choice of material delivery methods but also strengthens the monitoring, evaluation, and feedback process during training. At the evaluation stage, the fuzzy SERVQUAL method was used to accommodate subjective variations in participants' perceptions and expectations so that the assessment of service quality could be carried out more representatively, especially in conditions that contained uncertainty in the assessment. With this approach, the performance of the hybrid training model can be assessed more comprehensively, resulting in a stronger foundation in the formulation of SQI strategies.

The measurement results using fuzzy SERVQUAL show that all service quality dimensions still have negative gap values. This condition indicates that the services received by the participants did not meet their expectations. Compared to conventional SERVQUAL, the application of fuzzy logic provides an advantage in accommodating subjective and uncertain assessments, so that the evaluation results can more representatively illustrate the level of service quality gap. These findings are in line with those of previous studies in the professional training sector and the service industry, which reported that differences between customer perceptions and expectations remain a major problem in service quality evaluation [8]. The gaps found in all dimensions show that service quality problems not only occur in certain aspects but also reflect comprehensive conditions. Therefore, the results of the fuzzy SERVQUAL analysis can be used as a basis for determining the priority of service improvement based on each dimension's level of importance. These findings support the research of Priya and Roy [52], who stated that identifying gaps at the dimensional level helps organisations focus improvement efforts on the service attributes that have the most impact on customer satisfaction while strengthening the organisation's competitiveness.

Although Fuzzy SERVQUAL can identify service attributes that require attention, this method does not yet provide a mechanism for determining the corrective steps to be taken. These limitations are overcome through the integration of TRIZ, which is used to systematically develop solutions based on the contradictions that arise during the provision of services. This approach allows organisations to find improvement alternatives that can balance the need for improving service quality with various operational limitations. The findings of this study are in line with those of Shie *et al*. [53], who showed that the combination of service quality evaluation methods and TRIZ can result in more targeted and realistic improvement strategies. In this study, the integration of fuzzy SERVQUAL and TRIZ not only produces information about the level of service quality gap but also translates the evaluation results into recommendations that can be implemented. Thus, the proposed approach has a broader function than the service quality measurement method in general because it can be used as a basis for decision-making and innovation strategy preparation in the implementation of digital-based OSH training. From a practical perspective, this framework helps training providers set objective improvement priorities, develop more systematic service improvement programmes, and support ongoing efforts to improve training quality

5. CONCLUSION

This study addresses the gap of the previous study by integrating fuzzy SERVQUAL and TRIZ to evaluate the service quality weaknesses in AK3U certification training and develop a more targeted improvement strategy. The results of Fuzzy SERVQUAL's analysis showed a negative gap across all service dimensions, indicating that the participants' experience had not fully met their expectations. The most prominent gaps relate to the organisers' attention, information clarity, and suitability of training materials. The use of fuzzy logic in this study helps produce stronger assessments because it can accommodate elements of uncertainty and subjectivity in service evaluation.

Furthermore, TRIZ is used to translate the gap identification results into a more systematic and innovative alternative solution. The recommendations include the implementation of a hybrid training model, improvement of information delivery, preparation of

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modules based on participant needs, and strengthening of the training monitoring system. These solutions can increase the learning process's efficiency, flexibility, and effectiveness. However, the study is still limited to a single training provider, and the proposed recommendations have not been empirically tested. Therefore, further research is needed to validate these recommendations in the context of broader training services

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