Proceedings of the 7th African International Conference on Industrial Engineering and Operations Management
Cape Town, South Africa, May 13-15, 2026

Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/AF07.20260429
Published: May 13, 2026

Service Configuration Optimization for Canal Boat Transportation Using a TOPSIS-Based Taguchi Method: A Case Study of the Saen Saep Canal, Bangkok, Thailand

Sorrapong Charoenkittayawut
School of Industrial Engineering
Institute of Engineering
Suranaree University of Technology
Nakhon Ratchasima, Thailand
sorrapongc@gmail.com

Natdanai Chanlawong
School of Industrial Engineering
Institute of Engineering
Suranaree University of Technology
Nakhon Ratchasima, Thailand
natdanai@sut.ac.th

Abstract

The study aims to optimize service configuration in the Saen Saep canal boat system to enhance passenger satisfaction, with a focus on inbound services toward inner urban areas of Bangkok during weekday morning peak hours. A TOPSIS-based Taguchi method was employed for service optimization. Primary data were collected through a questionnaire survey of canal boat passengers using nine service scenarios generated by an L9 orthogonal array. The results indicate that the optimal service configuration during the morning peak period consists of moderate passenger density, where standing passengers are present but an acceptable level of personal space is maintained; a moderate vessel speed that balances travel efficiency with navigational safety; on-time arrival; and a waiting time exceeding 10 minutes, which is still perceived as acceptable under the optimal conditions. Passenger density is identified as the most influential service factor affecting passenger satisfaction, followed by vessel speed, waiting time, and punctuality. These findings provide practical implications for improving operational efficiency and service quality, thereby enhancing passenger satisfaction in canal boat transportation during peak hours.

Keywords
Service configuration optimization, Canal boat transportation, TOPSIS, Taguchi method, Saen Saep canal

1. Introduction
Water transportation is considered a crucial component of urban transport systems, particularly in large cities with extensive networks of rivers and canals (Zacharias 2026). It serves as an effective alternative for alleviating traffic congestion and reduces travel demand on road networks. Bangkok is widely recognized as one of the rapidly urbanizing cities, characterized by substantial urban expansion and severe traffic congestion. Therefore, water-based transportation in Bangkok is an alternative mode that offers convenience, time efficiency, and cost savings while effectively avoiding traffic congestion (Bangkok Metropolitan Administration 2019).

The Saen Saep Canal serves as an alternative mode of transportation, facilitating access from the eastern part of the city to its inner urban areas (Zacharias 2026). According to a report by the Marine Department (2025), the number of passengers using the Saen Saep canal boat service exceeded 10.88 million in 2024. On average, this corresponded to around 29,902 passengers per day, with weekday ridership increasing approximately 34,964 passengers per day in 2024 (Marine Department 2025). Despite its importance, the current operation of the Saen Saep canal boat service continues to face structural and service quality challenges that contribute to passenger dissatisfaction (Marine Department 2025). These include extended waiting time, passenger crowding that often exceeds acceptable standards—particularly during weekday peak hours—as well as vessel speed and on-time arrival, all of which are critical factors influencing passenger satisfaction (Marine Department 2025). However, efforts to address these issues often lead to trade-offs that may exacerbate other problems. For instance, increasing vessel speed may reduce waiting time and improve on-time arrival; however, such adjustments may compromise safety and place additional stress on canal embankment structures. Consequently, these challenges are inherently complex and multi-dimensional, requiring the careful design of optimal operational parameters to balance system efficiency with passenger needs and satisfaction.

Although the Marine Department (2024) has conducted continuous surveys on passenger satisfaction for the Saen Saep canal boat service over several years, a clearly defined and systematic service standard framework remains limited. This absence of standardized benchmarks constrains the objective evaluation of service performance and hinders systematic service improvement planning, as there are no consistent reference criteria for performance comparison and target setting. Therefore, an essential starting point for service system design is the analysis of the demand-side requirements to accurately capture user needs (Broaddus et al. 2009). In addition, incorporating the voice of customers, including both current users and potential target groups, is crucial for understanding service expectations (APICS 2017). Such an approach can effectively support the service design strategies and improvement directions for the Saen Saep canal boat system.

Previous studies addressing complex multi-objective problems have increasingly adopted an integrated approach combining the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and the Taguchi method (Agrawal and Kaur 2019; Verma et al. 2018). This hybrid approach has been widely applied in multi-response optimization contexts, including logistics and transportation (Miao et al. 2018), energy systems (Mojaver et al. 2020), and product design (Chang and Chen 2014). TOPSIS is a widely used multi-criteria decision-making technique for ranking alternatives based on their relative closeness to an ideal solution, and it is particularly effective in transforming multi-response problems into a single composite performance index (Ic et al. 2014). In contrast, the Taguchi method employs orthogonal arrays in experimental design to efficiently reduce the number of required experimental runs while maintaining robust analytical capability (Ic et al. 2014). The integration of these two methods therefore enhances the efficiency and reliability of identifying optimal parameter settings in complex systems. Moreover, this combined approach provides a more systematic and structured framework for optimization compared to conventional trial-and-error methods.

The objective of this study is to optimize the service configuration of the Saen Saep canal boat transportation system using a TOPSIS-based Taguchi approach to improve service performance and better meet passenger needs and satisfaction. This study simultaneously considers key service factors, namely waiting time, passenger density, vessel speed, and punctuality, as crucial determinants of passenger satisfaction in canal boat transportation services (Marine Department 2024). The analysis specifically focuses on service conditions during weekday peak hours, with particular emphasis on inbound routes toward the inner urban areas of Bangkok. Therefore, the findings of this study reflect passenger preferences and can be utilized to formulate policy recommendations for effective planning and management of the Saen Saep canal boat service in alignment with passenger satisfaction.

2. Literature Review

2.1 Service quality

Service is inherently complex and difficult to define, as its meaning varies widely across contexts and can be viewed either as a process or as an outcome delivered to customers (Lakunza et al. 2013). In the context of service quality, one of the most widely adopted frameworks is SERVQUAL, originally developed by Parasuraman et al. (1985). SERVQUAL is based on a multi-dimensional approach and was derived from the service quality gap model, which conceptualizes service quality as the discrepancy between customers' expectations and their perceptions of the service received. In its initial development, SERVQUAL comprised ten dimensions, including tangibles, reliability, responsiveness, communication, credibility, security, competence, courtesy, understanding/knowing customers, and access. Subsequently, Parasuraman et al. (1988) refined the model into five core dimensions: tangibles, reliability, responsiveness, assurance, and empathy. However, prior studies have suggested that the dimensions of service quality may vary depending on the specific research context (Coulthard 2004).

In the context of urban water transportation, particularly canal boat services, this study focuses on identifying optimal service configuration parameters. These parameters are expected to influence only certain dimensions of service quality, rather than all SERVQUAL components. Specifically, the study emphasizes reliability, responsiveness, and assurance (including safety), as these dimensions are directly affected by operational factors such as waiting time, passenger density, vessel speed, and punctuality (Marine Department 2024). Consequently, the dimensions of tangibles and empathy are not the primary focus of this study. In addition, previous research in public transportation has highlighted the importance of comfort as a key determinant of passenger satisfaction (Watthanaklang et al. 2024). Furthermore, in the specific context of the Saen Saep canal boat service, environmental factors are particularly critical (Kamber et al. 2026). These include engine noise, exhaust emissions, and fuel odors, all of which significantly affect passengers' perceived service quality and overall satisfaction. Accordingly, this study adopts a modified SERVQUAL framework consisting of five dimensions: reliability, safety and assurance, comfort, responsiveness, and environment, to better reflect the characteristics of canal boat transportation services.

2.2 Service configuration

Service configuration refers to the design and management of key operational elements that determine how a service delivers value and meets the needs of customers or users (Luo et al. 2022). According to Lakunza et al. (2013), service configuration can be classified into two main contexts. The first refers to services without predefined service level agreements (SLAs), where a standardized service framework is applied to all customers, and specific service attributes are configured during the sales process based on customer requirements. The second context involves services with predefined SLAs, in which service characteristics and conditions are specified in advance to guide future service provision.

In the context of this study, service configuration is defined as the design and arrangement of key operational attributes that govern how a service system delivers value to users. A review of the literature indicates that passengers place significant importance on waiting time, passenger density, vessel speed, and service punctuality, all of which are key determinants of service performance and passenger satisfaction (Maritime Department 2024). However, service configuration in public transportation systems is inherently dynamic and characterized by strong interdependencies among system components, where changes in one attribute may lead to cascading effects on others, creating trade-offs among performance criteria (Coelho et al. 2025).

A systematic review of the application of Multi-Criteria Decision-Making (MCDM) methods in passenger transportation highlights the increasing use of fuzzy-based techniques, such as Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Fuzzy Analytic Hierarchy Process (Fuzzy-AHP), and Decision-Making Trial and Evaluation Laboratory (DEMATEL), to address uncertainty in complex decision-making problems involving multiple alternatives and conflicting criteria (Kamber et al. 2026). These methods provide a systematic framework for evaluating and selecting optimal service configurations by balancing trade-offs among multiple performance dimensions, making them particularly suitable for complex service systems such as public transportation.

However, despite these advancements, the application of integrated approaches combining optimization techniques and MCDM in urban water transport systems remains limited. Studies focusing on the optimization of service configuration for canal-based passenger transport in high-density urban environments, such as Bangkok, are still scarce, despite the system's complexity in terms of fluctuating demand, congestion, and operational constraints. Therefore, this study aims to address this gap by proposing a TOPSIS-based Taguchi approach to optimize service configuration under multiple evaluation criteria.

3. Methods

3.1 Research design

This study applied a TOPSIS-based Taguchi approach to optimize the service configuration of the Saen Saep canal boat transportation system. The experimental design followed the Taguchi method, employing an L9 (3^4) orthogonal array. The service factors were derived from the passenger dissatisfaction report of the Marine Department (2024) and included four key factors: waiting time, passenger density, vessel speed, and punctuality, each classified into three levels as presented in Table 1 and Table 2.

Table 1. Experimental design based on the Taguchi method (L9) used in the study

Scenarios/Runs	**Levels of service factors (control factors)**			
	Waiting time	**Passenger density**	**Vessel speed**	**Punctuality**
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Table 2. Service factors (control factors) and their corresponding levels

Service factors	**Levels**	**Description**
Waiting time	1	Less than 5 minutes.
	2	Approximately 5-10 minutes.
	3	More than 10 minutes.
Passenger density	1	An extremely high level of passenger density, characterized by closely packed standing conditions that severely restrict passenger movement.
	2	A high level of passenger density, characterized by shoulder-to-shoulder standing conditions with reduced interpersonal space, requiring passengers to carry backpacks in front to conserve space; movement becomes increasingly constrained, although still tolerable.
	3	A moderate level of passenger density, characterized by fully occupied standing areas with passengers filling the aisle, while still maintaining sufficient personal space to allow limited movement, such as using a mobile phone or carrying a backpack without physical contact with others.
Vessel speed	1	A low vessel speed prioritizing safety (approximately 20 km/h).
	2	A moderate vessel speed, balancing travel efficiency and safety in accordance with navigation standards (approximately 24 km/h).
	3	A high vessel speed at the maximum level permitted by regulations (approximately 28 km/h).
Punctuality	1	The vessel arrives on time, in accordance with the scheduled or expected time.
	2	The vessel arrives approximately 5–10 minutes later than the scheduled or expected time.
	3	The vessel arrives more than 10 minutes later than the scheduled or expected time.

3.2 Source of data
This study utilized primary data collected from a passenger satisfaction survey of Saen Saep canal boat users. The analysis was conducted using experimentally designed service scenarios representing inbound services along the Saen Saep Canal toward the inner urban areas of Bangkok during weekday morning peak hours.

3.3 Population and sample
The population of this study comprised passengers using the Saen Saep canal boat service on inbound routes toward the inner urban areas of Bangkok. A convenience sampling technique was employed to collect data from passengers travelling on inbound routes toward inner Bangkok during weekday morning peak hours. According to Cochran's formula (Cochran 1977), the required sample size was estimated at 385 respondents. However, an additional 20

questionnaires were distributed to account for potential invalid or unusable responses, resulting in a total of 405 questionnaires. Of these, 402 were usable, representing 99.26% of the total responses collected.

3.4 Research instrument

The research instrument was a questionnaire comprising nine scenarios constructed based on the Taguchi method (L9 orthogonal array), as presented in Tables 1 and 2. The questionnaire was divided into three versions: Version I (Scenarios 1–3), Version II (Scenarios 4–6), and Version III (Scenarios 7–9). Each respondent was randomly assigned to complete only one version, corresponding to three of the nine scenarios, to reduce response fatigue and ensure data quality. An example of Scenario 1 used in the study is presented as follows:

Scenario 1: '*Assume that you are travelling on a Saen Saep canal boat toward the inner urban areas of Bangkok during weekday morning peak hours (7:00–9:00 a.m.). Upon arriving at the pier, you wait no longer than 5 minutes. After boarding, the boat is extremely crowded, requiring passengers to stand in very close proximity with severely limited mobility. The boat operates at a relatively low speed, prioritizing safety (approximately 20 km/h), and arrives at the destination on time.*'

The questionnaire items used to assess passenger satisfaction with service quality in the presented scenarios were adapted from the SERVQUAL framework (Parasuraman et al. 1988) and contextualized for public boat transportation services. The instrument comprised five dimensions: reliability (3 items), safety and assurance (4 items), comfort (4 items), responsiveness (3 items), and environment (3 items), as presented in Table 3. Responses were measured using a five-point Likert scale ranging from 'very satisfied' (5) to 'very dissatisfied' (1). Prior to the main data collection, the research instrument was assessed for content validity by a panel of experts, and the results indicated satisfactory content validity. A pilot study was subsequently conducted to evaluate reliability in terms of internal consistency. The overall Cronbach's alpha coefficient was 0.937. For individual service quality dimensions, the Cronbach's alpha values for reliability, safety and assurance, convenience, responsiveness, and environment were 0.904, 0.863, 0.700, 0.829, and 0.987, respectively. These findings confirm that the instrument exhibits strong internal consistency, supporting its use in the main data collection phase.

To determine the relative weights of the five service quality dimensions, a Kano-based questionnaire was employed. The instrument consisted of 17 paired items (34 items in total), comprising both functional (positive) and dysfunctional (negative) questions (Kano et al. 1984). Responses to each question are classified into five levels: 'like very much', 'must-be/normal', 'neutral', 'acceptable', and 'dislike' (Table 3).

Table 3. Components of passenger satisfaction measurement adapted from the SERVQUAL framework

Components	Description	Indicators
Reliability	The ability of the passenger boat service to operate consistently and predictably.	▪ Waiting time for the passenger boat ▪ Adequacy of boat service frequency during peak hours ▪ Travel time to reach the destination
Safety and Assurance	Passengers' perceptions of the service's ability to minimize risks or hazards throughout the journey and to ensure their safety during use.	▪ Safety of the passenger boat while in operation ▪ Safety when boarding and alighting from the boat ▪ Stability (degree of swaying) of the passenger boat ▪ Availability of life-saving equipment in emergency situations
Comfort	Passengers' perceptions of the physical environment within the boat, including its suitability for service provision, support for travel and usability, and its ability to avoid causing satisfaction or dissatisfaction among users.	▪ Comfort within the passenger boat ▪ Space available for passengers and their belongings ▪ Convenience of boarding and alighting ▪ Protection from canal water splashing onto passengers

Components	Description	Indicators
Responsiveness	Passengers' perceptions of the capability of boat staff to deliver services and their readiness to provide timely assistance to passengers.	▪ Staff assistance to passengers during boarding and alight ▪ Staff willingness to assist passengers when needed ▪ Efficiency of staff in fare collection
Environment	Passengers' perceptions of environmental quality or pollution arising from the operation of the passenger boat service.	▪ Noise level of the boat engine ▪ Smoke or soot emitted from the boat engine ▪ Odor of fuel from the boat engine

3.5 Data analysis

The procedure in this study followed the TOPSIS-based Taguchi optimization approach (Agrawal and Kaur 2019; Verma et al. 2018). The steps of the research process were as follows:

Step 1: Design the experiment according to the Taguchi method. In this study, the L9 (3^4) orthogonal array was employed as shown in Table 1.

Step 2: Calculate the signal-to-noise ratio (S/N ratio). After collecting the survey data, the S/N ratios for each experimental run (L9) were calculated. The S/N ratio is a measure of system robustness that assesses the relationship between the signal (desired performance) and the noise (uncontrollable factors). In this study, the 'larger-the-better' criterion was adopted to determine the optimal conditions that maximize passenger satisfaction with the boat service. The S/N ratio is calculated as follows in Eq. (1):

$$\eta_{ij} = -10 \log\left(\frac{1}{n}\sum_{k=1}^{n}\frac{1}{y_{ijk}^2}\right) \quad (1)$$

Step 3: Construct the decision matrix based on the calculated S/N ratios in Eq. (2).

$$D = \begin{bmatrix} \eta_{11} & \cdots & \eta_{1j} \\ \vdots & \ddots & \vdots \\ \eta_{m1} & \cdots & \eta_{ij} \end{bmatrix} \quad (2)$$

where i= 1,2,…m represents the set of alternatives or scenarios, and j=1,2,…,r represents the service factors.

Step 4: Determine the weights of the five service quality dimensions based on the Kano model (Kano et al. 1984). The extent of satisfaction (better) reflects the increase in satisfaction when a particular factor is improved, whereas the extent of dissatisfaction (worse) represents the decrease in satisfaction when that factor is not fulfilled or performs poorly. In this study, the satisfaction coefficients derived using the method of Berger et al. (1993) were used to determine the weights (w) for reliability, safety and assurance, comfort, responsiveness, and environment, which are 0.183, 0.214, 0.196, 0.206, and 0.202, respectively.

Step 5: Construct the normalized decision matrix using Eq. (3).

$$\eta_{ij}^{*} = \frac{\eta_{ij}}{\sqrt{\sum_{i=1}^{m}\eta_{ij}^2}} \qquad i= 1,2,\ldots m;\ j=1,2,\ldots,r \quad (3)$$

Step 6: Construct the weighted normalized decision matrix using Eq. (4).

$$v_{ij} = w_j \eta_{ij}^{*} \quad (4)$$

where w_j represents the weights of j-th service quality dimension and $\sum_{j=1}^{n} w_j = 1$.

Step 7: Calculate the ideal solution by determining both the positive ideal solution (A^+) using Eq. (5), which represents the best possible alternative, and the negative ideal solution (A^-) using Eq. (6), which represents the worst possible alternative. Here, J denotes the set of criteria for which higher values are preferred, while J′ represents the set of criteria for which lower values are preferred.

$$A^+ = \{v_1^+, v_2^+, \dots, v_n^+\} \quad \text{where } v_j^+ = \begin{cases} \max(v_{ij}), & j \in J \\ \min(v_{ij}), & j \in J' \end{cases} \tag{5}$$

and

$$A^- = \{v_1^-, v_2^-, \dots, v_n^-\} \quad \text{where } v_j^- = \begin{cases} \min(v_{ij}), & j \in J \\ \max(v_{ij}), & j \in J' \end{cases} \tag{6}$$

Step 8: Calculate the separation measures from the positive ideal solution and the negative ideal solution using Eq. (7) and (8), respectively.

$$S_i^+ = \left[\sum_{j=1}^{r}(v_{ij} - v_j^+)^2\right]^{1/2} \tag{7}$$

$$S_i^- = \left[\sum_{j=1}^{r}(v_{ij} - v_j^-)^2\right]^{1/2} \tag{8}$$

Step 9: Measure the relative closeness using Eq. (9). The larger the value Ci indicates a preferred alternative.

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-} \tag{9}$$

4. Data Collection

Data for this study were collected using a non-probability sampling approach, specifically convenience sampling. Data collection was conducted across several piers at different times and on different days (multi-site and multi-time). A team of ten research assistants supported the data collection process.

The procedures began with the researcher training the research assistants on proper data collection practices, including self-introduction, explaining the research objectives, instruments, and expected benefits, addressing respondents' questions, and expressing appreciation. Field practice was also conducted to ensure familiarity with on-site operations.

Subsequently, the questionnaires (Versions I, II, and III) were equally distributed among the research assistants, along with assigned piers for data collection. After each survey, the assistants checked the completeness of responses on-site and marked any issues for later review. All completed questionnaires were then returned to the researcher, who verified their accuracy and completeness, clarified any marked issues with the assistants, and finally entered the data into Microsoft Excel.

5. Results

This section presents the analytical results based on the procedures described in the previous section. Four service-related factors—waiting time, passenger density, vessel speed, and punctuality—were examined at three levels each. Additionally, five response variables—reliability, safety and assurance, comfort, responsiveness, and environment—were incorporated to assess passenger satisfaction.

In the first step, the analysis begins with the computation of the decision matrix using Eq. (1). The raw survey data are transformed into signal-to-noise (S/N) ratios using the 'larger-the-better' criterion, as presented in Table 4. The S/N-based decision matrix is then normalized using Eq. (2), and the resulting normalized matrix is presented in Table 5. Using the assigned weights for reliability (0.183), safety and assurance (0.214), comfort (0.196), responsiveness (0.206), and environment (0.202), the weighted normalized decision matrix is computed, as shown in Table 6. In the next step, the positive and negative ideal solutions for each response variable are determined using Eq. (5) and Eq. (6). These values are summarized in Table 6 and are obtained by selecting the maximum and minimum values in each column of the weighted normalized matrix, respectively. The maximum values represent the positive ideal solution, whereas the minimum values represent the negative ideal solution.

Table 4. Decision matrix of S/N ratios

Scenarios/Runs	Reliability	Safety & Assurance	Comfort	Responsiveness	Environment
1	0.331	0.277	0.237	0.265	0.175
2	0.361	0.360	0.324	0.331	0.342
3	0.341	0.336	0.370	0.356	0.323
4	0.322	0.295	0.281	0.303	0.296
5	0.377	0.342	0.346	0.344	0.367
6	0.343	0.351	0.371	0.338	0.391
7	0.277	0.277	0.278	0.294	0.190
8	0.270	0.357	0.354	0.363	0.382
9	0.362	0.386	0.404	0.388	0.437

Table 5. Normalized decision matrix

Scenarios/Runs	Reliability	Safety & Assurance	Comfort	Responsiveness	Environment
1	0.331	0.277	0.237	0.265	0.175
2	0.361	0.360	0.324	0.331	0.342
3	0.341	0.336	0.370	0.356	0.323
4	0.322	0.295	0.281	0.303	0.296
5	0.377	0.342	0.346	0.344	0.367
6	0.343	0.351	0.371	0.338	0.391
7	0.277	0.277	0.278	0.294	0.190
8	0.270	0.357	0.354	0.363	0.382
9	0.362	0.386	0.404	0.388	0.437

Table 6. Weighted normalized decision matrix

Scenarios/Runs	Reliability	Safety & Assurance	Comfort	Responsiveness	Environment
1	0.061	0.059	0.046	0.055	0.035
2	0.066	0.077	0.063	0.068	0.069
3	0.062	0.072	0.072	0.073	0.065
4	0.059	0.063	0.055	0.062	0.060
5	0.069	0.073	0.068	0.071	0.074
6	0.063	0.075	0.072	0.069	0.079
7	0.051	0.059	0.054	0.060	0.038
8	0.049	0.076	0.069	0.075	0.077
9	0.066	0.083	0.079	0.080	0.088
Positive ideal solution	0.069	0.083	0.079	0.080	0.088
Negative ideal solution	0.049	0.059	0.046	0.055	0.035

Subsequently, the separation measures from the positive and negative ideal solutions for each response variable are calculated using Eq. (7) and Eq. (8). The relative closeness coefficients are then computed using Eq. (9), with the results summarized in Table 7.

After ranking the service scenarios based on their relative closeness coefficients, Scenario 9 is identified as the optimal configuration, achieving the highest relative closeness value and maximizing passenger satisfaction across all five service quality dimensions. This scenario represents conditions in which a waiting time exceeding 10 minutes remains acceptable. The vessel maintains a moderate passenger density, allowing standing passengers while preserving a reasonable level of personal space and limited mobility. It operates at a moderate speed (approximately 24 km/h), balancing travel efficiency and safety, and ensures on-time arrival in accordance with navigation standards.

Table 7. Computation of separation measures and closeness coefficients

Scenarios/Runs	S_i^+	S_i^-	C_i	**Rank**
1	0.072	0.011	0.136	9
2	0.028	0.047	0.626	6
3	0.028	0.048	0.631	5
4	0.047	0.029	0.383	7
5	0.022	0.053	0.703	3
6	0.018	0.057	0.760	2
7	0.066	0.010	0.137	8
8	0.026	0.055	0.679	4
9	0.003	0.073	0.963	1

The analysis of main effects, as summarized in Table 8, provides insight into the relative influence of each service factor on passenger satisfaction. Passenger density exhibits the greatest influence, with the highest delta value (0.566), indicating substantial variation across its levels. The remaining factors are ranked as vessel speed (0.167), waiting time (0.151), and punctuality (0.093). The optimal configuration corresponds to Level 2 for waiting time, Level 3 for passenger density, Level 2 for vessel speed, and Level 1 for punctuality.

Table 8. Main effects and optimal levels of service factors

Level	**Waiting time**	**Passenger density**	**Vessel speed**	**Punctuality**
1	0.464	0.219	0.525	0.601
2	0.616	0.669	0.658	0.508
3	0.593	0.785	0.490	0.564
Delta	0.151	0.566	0.167	0.093
Rank	3	1	2	4
Optimal level	Level 2	Level 3	Level 2	Level 1

6. Conclusion

This study primarily adopted the passengers' perspective, focusing on their satisfaction with service quality under different service scenarios. The findings suggest that the optimal alternative for improving passenger boat service quality during the morning peak period, particularly on routes toward the inner urban area, involves a moderate passenger density that allows standing passengers in the aisle while still maintaining an acceptable level of personal space, a moderate vessel speed that balances travel efficiency with navigational safety standards, and on-time arrival at the destination according to the scheduled timetable. In addition, the result indicates that a waiting time exceeding 10 minutes can be acceptable under this optimal service configuration.

Improving canal boat services should prioritize the management of passenger density within vessels. Excessive crowding not only reduces physical comfort but also restricts mobility, increases perceived safety risks, and negatively affects the overall travel experience. Therefore, maintaining an appropriate level of passenger occupancy is essential for ensuring service efficiency and enhancing passenger satisfaction.

Although the assessment of service quality is inherently subjective, the application of the S/N ratio as a key analytical measure enables the identification of service configurations that are both stable and widely acceptable to most passengers. Therefore, the findings of this study could serve as a practical guideline for improving the quality of boat services

Acknowledgements

The authors gratefully acknowledge the research assistants for their valuable support in data collection, particularly those from Santiratwitthayalai School who participated in the field survey of passengers using the Saen Saep canal boat service. Special thanks are extended to Thanyamon Nuanchome for assistance in training the research assistants for field data collection. The authors also appreciate all respondents for generously devoting their time to provide

valuable information, which serves as an important basis for improving the quality of the Saen Saep canal boat transportation service.

References

Agrawal, A. and Kaur, R., Engineering optimization of process parameters for polymers: an overview, *International Journal of Experimental Design and Process Optimisation*, vol. 6, no. 2, pp. 89–126, 2019.
APICS, *Supply chain operations reference model (SCOR) version 12.0*, APICS, Chicago, 2017.
Bangkok Metropolitan Administration, *Report on Water-Based Public Transportation Services in 2019*, Bangkok, 2019.
Berger, C., Blauth, R., Boger, D., Bolster, C., Burchill, G., Dumouchel, W., Pouliot, F., Richter, R., Rubinoff, A., Shen, D., Timko, M. and Walden, D., Kano's methods for understanding customer-defined quality, *Center for Quality Management Journal*, vol. 2, no. 4, pp. 3–36, 1993.
Broaddus, A., Litman, T. and Menon, G., *Transportation demand management*, Deutsche Gesellschaft für Technische Zusammenarbeit, Eschborn, 2009.
Chang, H.-C. and Chen, H.-Y., Optimization product from attractiveness using Taguchi and TOPSIS algorithm: a case study involving a passenger car, *Concurrent Engineering*, vol. 22, no. 2, pp. 135–147, 2014.
Cochran, W. G., *Sampling Techniques*, John Wiley & Sons, New York, 1977.
Coelho, P., Nobrega, R., Oliveira, L. and Humberto, M., The trade-off between equity and quality in public transportation: lessons from a Brazilian case study, *npj Sustainable Mobility and Transport*, vol. 2, pp. 1–12, 2025.
Coulthard, L. J. M., A review and critique of research using SERVQUAL, *International Journal of Market Research*, vol. 46, no. 4, pp. 479–497, 2004.
Ic, Y. T., Dengiz, B., Dengiz, O. and Cizmeci, G., TOPSIS based Taguchi method for multi-response simulation optimization of flexible manufacturing system, *Proceedings of the 2014 Winter Simulation Conference*, pp. 2147–2155, New Jersey, USA, 2014.
Kamber, E., Yücel, B. and Gümüş, M., A review on multi-criteria decision-making in passenger transportation: Trends, methods, and future directions, *Socio-Economic Planning Sciences*, vol. 103, pp. 102384, 2026.
Kano, N., Seraku, N., Takahashi, F. and Tsuji, S.-I., Attractive quality and must-be quality, *Journal of the Japanese Society for Quality Control*, vol. 14, no. 2, pp. 147–156, 1984.
Lakunza, J. A., Astiazaran, J. C. and Elejoste, M., Service model for the service configuration, *Proceedings of the Advances in Production Management Systems*, Berlin, Germany, 2013.
Luo, X.-G., Liu, L., Shang, X.-Z. and Zhang, Z.-L., Service configuration optimization for multiple customers considering service process information and time-varying service resources, *Computers & Industrial Engineering*, vol. 173, pp. 108710, 2022.
Marine Department (Thailand), *A Report on Passenger Density of the Saen Saep Canal Boat Service in 2024*, Bangkok, Thailand, 2025.
Marine Department (Thailand), *A Survey Report on Passenger Satisfaction and Dissatisfaction with the Saen Saep Canal Boat Service,* Bangkok, Thailand, 2024.
Miao, T., Tie-Dan, W. and Ding-Hong, P., Research on Taguchi TOPSIS method in logistics service quality, *Proceedings of the International Conference on Social Science and Education Reform (ICSSER 2018)*, Atlantis Press, pp. 233–236, 2018.
Mojaver, P., Khalilarya, S., Chitsaz, A. and Assadi, M., Multi-objective optimization of a power generation system based on SOFC using Taguchi/AHP/TOPSIS, *Energy Reports*, vol. 38, pp. 1–13, 2020.
Parasuraman, A., Zeithaml, V. A. and Berry, L. L., A conceptual model of service quality and its implications for future research, *Journal of Marketing*, vol. 49, no. 4, pp. 41–50, 1985.
Parasuraman, A., Zeithaml, V. A. and Berry, L. L., SERVQUAL: A multiple-item scale for measuring consumer perceptions of service quality, *Journal of Retailing*, vol. 64, no. 1, pp. 12–40, 1988.
Verma, R. K., Kumar, J., Kharwar, P. K. and Abhishek, K., TOPSIS based Taguchi approach for multi-criteria optimization in quality and productivity characteristics, *Proceedings of the 4th International Conference on Computers and Management (ICCM 2018)*, New Delhi, India, 2018.
Watthanaklang, D., Jomnonkwao, S., Champahom, T. and Wisutwattanasak, P., Exploring accessibility and service quality perceptions on local public transportation in Thailand, *Case Studies on Transport Policy*, vol. 15, pp. 101144, 2024.
Zacharias, J., Water-based public transportation in Bangkok – efficiency, efficacy, and carrying capacity, *Case Studies on Transport Policy*, vol. 23, pp. 1–8, 2026.

Biographies

Sorrapong Charoenkittayawut is a master's student in Systems Engineering at the Institute of Engineering, Suranaree University of Technology, Nakhon Ratchasima, Thailand. He holds bachelor's and master's degrees in Economics from Kasetsart University, Bangkok, Thailand, and a master's degree in Economics and Econometrics from the University of Essex, United Kingdom. He currently serves as a full-time lecturer in the Department of Educational Policy, Management, and Leadership, Faculty of Education, Chulalongkorn University, Bangkok, Thailand. His research interests include the application of quantitative and statistical methods to address problems in the service and business sectors.

Natdanai Chanlawong is a full-time lecturer at the School of Industrial Engineering, Institute of Engineering, Suranaree University of Technology, Nakhon Ratchasima, Thailand. He holds bachelor's and master's degrees in Industrial Engineering and a doctoral degree in Industrial Systems and Environmental Engineering from Suranaree University of Technology. His research interests include digital logistics, logistics and supply chain management, operations research, epidemic modeling, and systems engineering.