RESEARCH ARTICLE

Passenger Service Satisfaction Evaluation of Jakarta-Bandung High-Speed Railway

Liu Shuyuan[1,*] and Utomo Sarjono Putro[2]

ABSTRACT

As competition in the passenger transportation industry intensifies, high-speed railway must continuously improve service quality to win passenger satisfaction and secure a place in the competitive market. The Jakarta-Bandung High-Speed Railway (JBHSR), Indonesia's and Southeast Asia's first high-speed rail, commenced operation in October 2023. This study aims to identify areas for service improvement by measuring and evaluating passenger satisfaction and proposing optimization suggestions. Combining domestic and international service quality evaluation schemes and customer satisfaction models, this study employs the Analytic Hierarchy Process (AHP) to construct a passenger satisfaction evaluation system for high-speed rail services from three dimensions: perceived quality, expected value, and perceived value. A passenger satisfaction survey was conducted, and the results were analyzed using AHP and Fuzzy Comprehensive Evaluation (FCE) methods to calculate satisfaction scores. The Importance-Performance Analysis (IPA) revealed that aspects such as ease of ticket purchasing, accuracy of train operation information, and punctuality scored highly in terms of satisfaction. However, items categorized under 'Concentrate Here' and 'Low Priority' quadrants require further optimization. This study benchmarks successful practices from other countries' HSR systems and proposes specific improvement measures, including installing free Wi-Fi at stations and on trains, expanding parking capacity with an online reservation system, increasing the number of escalators and elevators at Padalarang Station, and installing electronic displays and enhancing ground signage for better visibility of carriage positions. These measures aim to improve the quality of HSR services and enhance passenger satisfaction.

Keywords: AHP-FCE, High-speed railway, Passenger satisfaction evaluation, Service quality.

1. INTRODUCTION

As an integral part of public transportation, railway development plays a crucial role in promoting social progress. Railway passenger services are closely tied to the daily lives of the public, serving as essential public services that directly impact livelihoods. The completion of Jakarta-Bandung High-Speed Railway (JBHSR) offers the public more travel options and marks the transition of Indonesian passenger rail transportation from conventional to HSR. This project symbolizes technological advancement and Chinese-Indonesian cooperation, representing a significant step towards modernizing the country's public transportation system. However, the success of the JBHSR depends not only on its technology

and managerial efficiency but also on how it performs in a highly competitive market environment.

The JBHSR competes with a variety of transportation options, including high-speed buses, conventional railways, regional Light Rail Transit (LRT), and air services. Each mode presents unique advantages and challenges, which directly affect travelers' preferences. Detailed comparison is presented in Table I.

Although the JBHSR boasts inherent advantages in comfort and speed, high-speed buses retain a stable market share due to their flexibility and affordability. If the concepts of comfort and speed in high-speed rail (HSR) do not strongly resonate with the public, passenger traffic on the HSR may be compromised. Moreover, existing railways between the two locations directly threaten the

TABLE I: Comparison of Transportation Modes for Jakarta-Bandung Route

Mode of transportation	Advantages	Disadvantages
Highway	Flexible and affordable fares	Traffic congestion, longer travel time (over 3 h).
Existing railway	No traffic jams, moderate fare	Low speed, longer travel time (around 3 h).
LRT	Flexible	Can only cover small sections and requires transfers.
Airplane	Short direct flight time (40 min)	Long check-in times, very limited direct flights, high fares.

core business of the JBHSR. If these existing lines are upgraded to speeds exceeding 100 km/h, the competitive threat will increase. LRT is also a strong competitor. While airplanes cannot compete in travel time, their direct and fast service remains highly attractive to business travelers seeking to save time.

In the fiercely competitive transportation market, understanding the public's needs and expectations fully, as well as the gap between these and the current HSR services, is crucial. Taking passenger satisfaction as both the starting and ending point, it is essential to continuously improve the facilities and service quality of high-speed trains to enhance the competitiveness of high-speed rail in the passenger transport market.

Therefore, to meet the public's demand for transportation services and continuously improve the quality of HSR services, this study will first investigate the current status of JBHSR services before proposing optimization strategies. By establishing a scientific and reasonable evaluation system, the study will assess the quality of current high-speed railway services, identifying the key factors that influence passenger satisfaction. The study will analyze these factors to pinpoint weaknesses and gaps and will then offer targeted suggestions for improvements by benchmarking high-speed railway services from other countries. This approach will provide comprehensive optimization strategies to enhance passenger satisfaction.

2. BUSINESS ISSUE

With the completion and operation of JBHSR, the project not only marks a significant milestone in Indonesia's infrastructure development and public transportation reform but also provides fast and convenient transportation options, significantly reducing travel time between Jakarta and Bandung. However, the intensely competitive environment presents significant challenges to service quality and passenger satisfaction as public expectations continue to rise. These challenges necessitate a deeper investigation into the actual experience of the passengers using this service. Therefore, the study questions are as follows:

1. What is the current level of passenger service satisfaction under existing conditions?
2. What are the key areas or passenger concerns that JBHSR needs to prioritize for improvement?
3. How can these factors be improved to enhance passenger service satisfaction?

The objective of this study is to develop a measurement system on passenger service satisfaction for JBHSR, accurately measure current satisfaction levels, and provide

strategic recommendations for enhancing the quality of service to effectively meet passenger expectations.

3. LITERATURE REVIEW

Chou *et al.* (2011) suggest that human judgments are often ambiguous, making it challenging for passengers to accurately assign numerical values to evaluation criteria and satisfaction levels of airline service quality. Thus, using fuzzy set theory to handle this uncertainty is appropriate. Chen and Lin (2010) highlight that the quality of passenger service is determined by comparing passengers' expectations with their actual perceptions, making the evaluation inherently subjective. Consequently, the assessment of railway passenger service quality relies heavily on passengers' experiences. Railway companies can use these evaluation results to guide passenger expectations, ultimately enhancing satisfaction. In general, passenger satisfaction has the characteristics of subjectivity, dynamism, and ambiguity.

Building on this understanding of the subjective and dynamic nature of passenger satisfaction, various scholars have developed more structured methodologies to refine the evaluation process. Researchers employ methods such as the Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE) to provide more concrete and systematic approaches for measuring passenger satisfaction.

Huo and Jiang (2011) proposed twenty-seven evaluation indicators in their paper, the indicators are described in simple and understandable language, which can be useful for reference.

Liu (2013) lists thirty-seven evaluation indicators. The number of indicators is excessive, and not all passengers experience all indicators, for instance, six indicators relate to the website service, which cannot be accurately assessed by passengers who do not buy tickets online. However, one can extract the essential indicators that encompass high-speed rail station and train services from this list.

Chen *et al.* (2015) introduced nineteen evaluation indicators, organized into five categories: time experience, price experience, safety experience, information experience, and environmental experience. The study utilized AHP and FCE to conduct the analysis. Although these indicators cover most aspects of high-speed rail services, they do not adequately evaluate the competence and attitude of service personnel.

The Indonesia Ministry of Transportation's Regulation No. 7 of 2022 on the Implementation of HSR defines minimum service standards for HSR, categorizing indicators into seven aspects: safety, security, reliability, comfort, convenience, equality, and health. However, the evaluation indicators are overly detailed and do not cover staff competence.
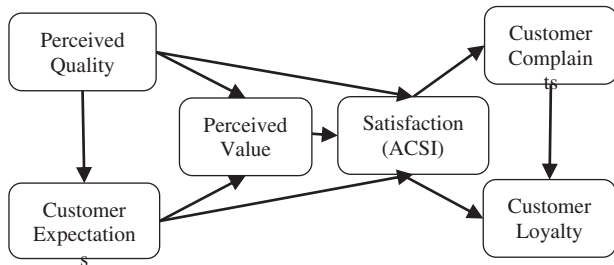
Fig. 1. American customer satisfaction index model.

Fig. 2. Importance-performance matrix index model.

Methods and Key Models for Passenger Satisfaction Evaluation applied in this study are as follows:

3.1. Assessment Methods

Analytic Hierarchy Process (AHP), proposed by Saaty (1980), is used to analyze complex problems and their internal relationships. It creates a hierarchical model with objective, criterion, and alternative layers, breaking down the problem into various influencing factors and combining them into a multi-criteria hierarchical system. By establishing pairwise comparison matrices, subjective evaluations are converted into measurable data, allowing AHP to determine the weight of each criterion and conduct qualitative and quantitative analysis.

Fuzzy Comprehensive Evaluation (FCE), proposed by Zadeh (1965), is a comprehensive judgment method that integrates multiple factors and indicators to assess a subject. It lists all factors influencing the overall objective and builds an evaluation indicator system. The weights and vectors of various indicators are determined through pairwise comparisons, resulting in a fuzzy evaluation set. These undergo fuzzy operations and normalization to quantify qualitative indicators, with multi-level calculations performed to obtain the final fuzzy comprehensive evaluation results.

Given the hierarchical nature and inherent ambiguity in assessing HSR passenger satisfaction, this study employs AHP to develop an evaluation system for HSR passenger satisfaction. By combining AHP with FCE method, the study quantitatively measures passenger opinions across various indicators within the system.

3.2. Assessment Models

3.2.1. American Customer Satisfaction Index (ACSI)

The ACSI model, initially proposed by Fornell *et al.* (1996) from the University of Michigan, is primarily used for assessing the quality of products and services offered by businesses. In this model, customer satisfaction is the target variable, while customer expectations, perceived quality, and perceived value are the causal variables. Customer complaints and customer loyalty are the result variables. The basic structure of the model is presented in Fig. 1.

3.2.2. ACSI Model

The ACSI model suggests that customer satisfaction is jointly determined by customer expectations, perceived quality, and perceived value. Dissatisfaction with service quality can lead to complaints, and customer loyalty depends on satisfaction and complaint resolution. The model connect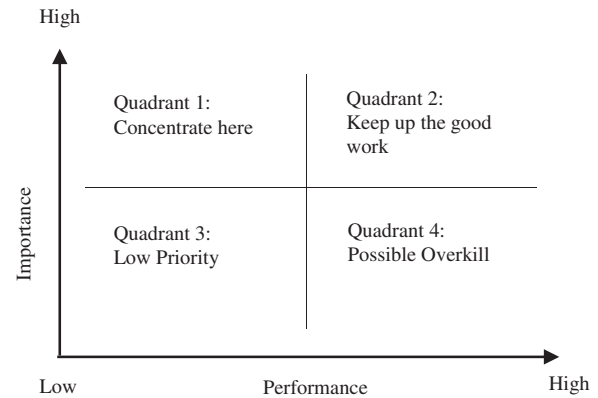s customer satisfaction with its determinants—customer expectations, perceived quality, and perceived value—and also links customer complaints and loyalty, impacting profitability. It objectively reflects customer evaluations of service quality and overall satisfaction through the customer consumption cognition process. However, it does not deeply explore the specific factors within service quality and their impact on satisfaction.

3.2.3. IPA Model

The Importance-Performance Analysis (IPA) model, introduced by Martilla and James (1977), is a structural tool used for qualitative analysis of the relationship between importance and satisfaction/performance. It lists all performance indicators for a product or service and scores them based on their importance and satisfaction from the customer's perspective. The indicators are then placed into four quadrants in the importance-satisfaction matrix, allowing businesses to address them according to their distribution, as seen in Fig. 2 for a description.

Indicators in the 'Keep up the Good Work' quadrant are crucial and exhibit high customer satisfaction; they represent the business's competitive advantages and should continue to be a focus. Indicators in the 'Concentrate Here' quadrant are important but show lower customer satisfaction, thus requiring immediate attention. Indicators in the 'Possible Overkill' quadrant, while less critical and highly satisfying to customers, offer little significance to business growth. Indicators in the "Low Priority" quadrant are not essential, with low customer satisfaction; although not a top concern, improvements here may increase their importance and influence.

3.3. Conceptual Framework

The conceptual framework is described in Fig. 3, which integrates ACSI model, identifying key customer satisfaction variables such as expectation, perceived quality, and value. The study adopts a multi-level indicator system specific to HSR services, utilizing methods like AHP and FCE to determine the importance and satisfaction scores of each indicator. Results are analyzed using IPA model to pinpoint areas requiring attention and improvement.
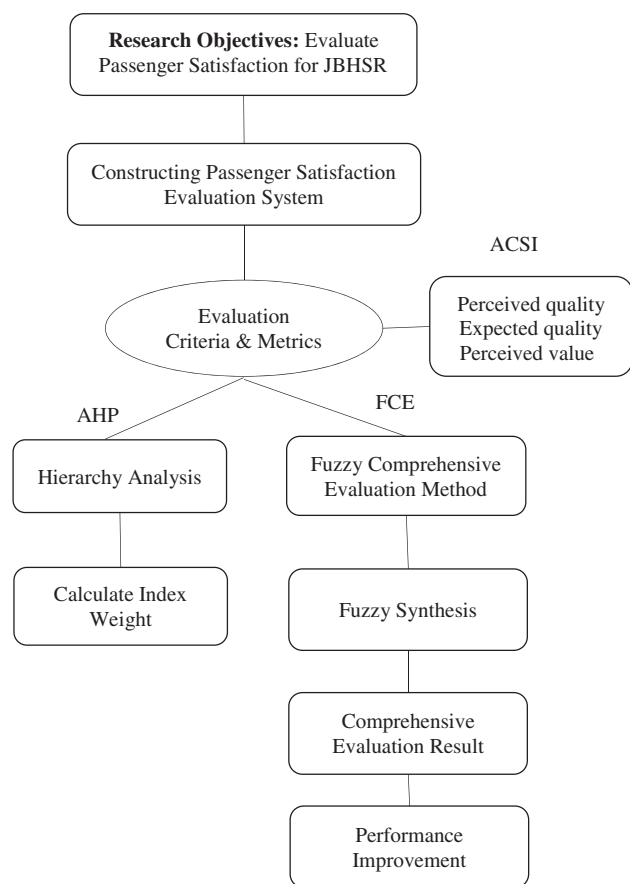
Fig. 3. Conceptual framework.

4. Methodology

4.1. Data Collection Method

The data collection method used in this study includes interviews with internal experts, questionnaire to JBHSR passengers, and focus group discussion:

1. *Interview with internal experts:* This study selected a panel of three senior HSR passenger transportation experts who conducted pairwise comparisons of indicators at various levels, using a 1–9 scale for their judgments. The importance values of each indicator were determined using AHP.
2. *Questionnaire for whoosh passengers*: A questionnaire was used to collect evaluations from passengers on JBHSR services, converting the final level indicators into survey questions.
3. *Focus Group Discussion*: A focus group discussion was held with the company's passenger service team to address areas of low passenger satisfaction and to suggest improvement measures, which are detailed in Chapter VI.

4.2. Data Collection Content

This study synthesized relevant literature to understand how researchers have selected various evaluation indicators from different perspectives to create diverse passenger satisfaction evaluation systems. Combining the characteristics of evaluation indicators referenced in section 3,

Literature Review, and considering the scope and content of this study, the following points should be fully considered when selecting evaluation indicators:

- The number of indicators should focus on key indicators to avoid overwhelming passengers.
- Indicators should cover both station and train services and include multiple sensory experiences such as sight, sound, and touch.
- Descriptions should be straightforward and free of excessive technical jargon.
- Indicators should be independent and highly distinct to maintain accuracy.

Based on the considerations mentioned above, the following 26 evaluation indicators were selected to assess JBHSR services:

1. Air quality, lighting, and temperature comfort on the high-speed train.
2. Cleanliness of the high-speed rail station and train.
3. Security order at the high-speed rail station and train.
4. Accessibility of public transportation to and from the high-speed rail station.
5. Ease of buying tickets.
6. Facilities for car parking.
7. Station internal signage.
8. Punctuality of the high-speed train.
9. Overall completeness and convenience of station and train facilities.
10. Convenience and simplification of the transfer process, especially for the feeder line at Padalarang.
11. High-speed train carriage and seating arrangements.
12. Provision of drinking water on the high-speed train.
13. Variety, taste, quality, and pricing of meals and products sold at the station and on the train.
14. warning and safety notices at high-risk areas in the high-speed rail stations and trains.
15. Comfort of the seating areas in the station and train.
16. Timeliness and accuracy of train operation information.
17. Network coverage and stability in the station and train.
18. Availability and maintenance of health and emergency medical facilities at the station and train.
19. Station entry security check & ticket verification service.
20. High-speed railway station waiting and boarding service.
21. Ticket check and disturbance level on high-speed train.
22. Availability of train staff.
23. Attitude and problem-solving capability of station and train staff.
24. Services for vulnerable groups, such as the elderly, disabled, pregnant, etc., at the station.
25. Pre-boarding expectations of service quality.
26. Overall satisfaction with station and train services (value for money satisfaction level).

4.3. Building the Evaluation Indicator System

After selecting twenty-six evaluation indicators, the next step involves classifying them to establish a clear and logical evaluation indicator system. By integrating the ACSI model with the actual operations of the JBHSR, a 4-level indicator system was developed:

1. *Define the Goal Variable:* The primary goal for this evaluation is overall passenger satisfaction, represented as the first-level indicator "A" in the evaluation system.
2. *Second-Level Indicators (Causal Variables):* These represent perceived quality, expected quality, and perceived value, labeled as "B1, B2, B3" in the evaluation system.
3. *Third-Level Indicators:* These further categorize the second-level indicators based on various aspects of HSR service. These include station and train service functions, service environments, personnel quality, overall expectations, and perceived value, labeled as "C1, C2, C3, C4, C5." The key content within these third-level indicators is the comparison between passenger expectations and perceived quality.
4. *Fourth-Level Indicators:* Each third-level indicator is further divided based on the specific HSR services provided:

   - *Service Functions:* Accessibility of public transportation to and from the high-speed rail station, ease of buying tickets, facilities for car parking, station internal signage, punctuality of the high-speed train, overall completeness and convenience of station and train facilities, convenience and simplification of the transfer process, especially for feeder line at Padalarang, high-speed train carriage and seating arrangements, provision of drinking water on the high-speed train, variety, taste, quality, and pricing of meals and products sold at the station and on the train, warning and safety notices at high-risk areas in the high-speed rail station and train, comfort of the seating areas in the station and train, timeliness and accuracy of train operation information, network coverage and stability in the station and train, availability and maintenance of health and emergency medical facilities at station and train.
   - *Service Environments:* Air quality, lighting, and temperature comfort on the high-speed train, cleanliness of the high-speed rail station and train, and security order at the high-speed rail station and train.
   - *Personnel Quality:* Station entry security check and ticket verification service, high-speed railway station waiting and boarding service, ticket checking, and disturbance level on the high-speed train, availability of train staff, attitude and problem-solving capability

   of station and train staff, services for vulnerable groups such as the elderly, disabled, pregnant, etc., at the station.
   - *Overall Expectations:* This includes pre-service quality expectations.
   - *Perceived Value:* This includes satisfaction with cost-effectiveness (ticket price versus perceived benefits).

Combining these categories, the final evaluation system includes 26 fourth-level indicators labeled as "D1–D26." These indicators, fundamental to the evaluation process, provide a comprehensive and straightforward method for gauging passenger satisfaction across various aspects of HSR service. This system facilitates direct evaluation and scoring within the survey questionnaire, ensuring thorough assessment of each aspect of the passenger experience and yielding actionable insights for service improvement.

4.4. Calculating the Weight of Evaluation Indicators

To accurately reflect the relative importance of each evaluation indicator in the context of passenger service satisfaction, this study employs AHP to calculate their weights.

In the evaluation indicator system, a pairwise comparison matrix is created for the indicators at each level to assess the relative importance of each pair. This assessment uses a $1-9$ scale, where the importance of each indicator pair is compared and corresponding values are assigned. The weights of each indicator are then calculated based on the values in the judgment matrix. The procedures of the AHP method are illustrated step-by-step as follows:

- *Step 1: Construct a pair-wise comparison matrix A (n × n):*

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & \cdots & a_{2n} \\ \cdots & \cdots & a_{ij} & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

where A, a_{ij} represents the relative importance of indicator a_i compared to a_j. If a_i is more important than a_j, then $a_{ij} > 1$. If they are equally important, then $a_{ij} = 1$.

- *Step 2: Judging matrix elements' importance*

Utilizing a 1-9 scale as depicted in Table II to evaluate the elements within the matrix facilitates a numerical assessment of their significance

- *Step 3: Calculate the priority vectors of evaluated factors*

Zhou and Chan (2017) detailed the method for calculating the weight vectors of evaluated factors using the common method of ANC (Average of Normalized Columns). This method is articulated through the following formula:

$$w_i = \frac{1}{n} \sum_{j=1}^{n} \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \ (i, j = 1, 2, \cdots, n) \quad (2)$$

where w_i is the weight for the i indicator.

TABLE II: Judging Matrix

Intensity importance	Definition
1	Equal importance
3	Weak importance of one over another
5	Essential or strong importance
7	Demonstrated importance
9	Absolute importance
2, 4, 6, 8	Intermediate values between the two adjacent judgement
Reciprocals of above nonzero	If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i

- *Step 4: Calculate the maximum eigenvalue*

To calculate the maximum eigenvalue for the judgment matrix, use the following formula:

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^{n} \frac{(Aw)_i}{w_i} \quad (3)$$

where *n* is the order of the matrix, *A* is the judgment matrix, w_i is the weight of the *i* indicator, and λ_{max} is the maximum eigenvalue.

- *Step 5: Consistency check*

Assuming *CI* represents the consistency index, (4) shows the calculation method:

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (4)$$

The consistency ratio, *CR* is the ratio of CI to RI as show in (5):

$$CR = \frac{CI}{RI} \quad (5)$$

where *RI* represents the average random index, calculated and presented in Table III.

If the Consistency Ratio $C < 0.1$, the consistency check is considered successful, indicating that the judgment matrix has passed the consistency test and the results are reliable.

4.5. Calculating the Passenger Satisfaction Degree

After determining the weights of each indicator using the AHP method, the satisfaction degree of each indicator is calculated based on the passenger satisfaction survey results using the FCE method.

- *Step 1: Determining the set of evaluation factors*

A set of *m* evaluation factors can be represented as a vector $U = \{u_1, u_2, \ldots, u_m\}$ which is the collection of various indicators that can characterize the characteristics of the evaluation target.

- *Step 2: Determining the set of appraisal grades*

The appraisal set can be represented as a vector $V = \{v_1, v_2, \ldots v_n\}$, in which n represents the number of levels in the appraisal. In this study, $n = 5$, the appraisal vector can be represented as $V = \{$very dissatisfied, dissatisfied, neutral, satisfied, very satisfied$\}$.

- *Step 3: Setting the fuzzy mapping matrix R*

If there are m factors and n levels of appraisal grades, the fuzzy appraisal matrix of all *m* factors can be derived and represented as a matrix *R* as follows:

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \quad (6)$$

In the above matrix notation for R, each row represents the set of appraisal membership degrees to the corresponding appraisal vector *V* for each evaluation factor u_i in the evaluation vector *U*.

- *Step 4: Determining the weight of each evaluation factor*

The weight vector can be represented by *W*, which is formulated by the AHP method in this study. For *m* evaluation factors, the weight can be represented by the vector $W = (w_1, w_2, \cdots w_m)$.

- *Step 5: Getting the appraisal result*

Compose the fuzzy comprehensive evaluation result vector, where *B* is the final appraisal vector, and *b* is each element of the final appraisal vector.

$$\begin{aligned} B &= (w_1, w_2, \cdots w_m) \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \\ &= (b_1, b_2, \cdots b_n) \end{aligned} \quad (7)$$

- *Step 6: Analyze the fuzzy comprehensive evaluation result*

TABLE III: Random Index Value *RI*

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.58

TABLE IV: JBHSR PASSENGER SATISFACTION EVALUATION SYSTEM

1st level	2nd level	3rd level	4th level
A passenger satisfaction	B1: Perceived quality	C1: Station and train service functions	D1: Accessibility of public transportation to and from the high-speed rail station
			D2: Ease of buying tickets
			D3: Facilities for car parking
			D4: Station internal signage
			D5: Punctuality of the high-speed Train
			D6: Overall completeness and convenience of station and train facilities
			D7: Convenience and simplification of transfer process, especially for feeder line at Padalarang
			D8: High-speed train carriage and seating arrangements
			D9: Provision of drinking water on the high-speed train
			D10: Variety, taste, quality, and pricing of meals and products sold at the station and on the train
			D11: Warning and safety notices at high-risk areas in the high-speed rail station and train
			D12: Comfort of the seating areas in the station and train
			D13: Timeliness and accuracy of train operation information
			D14: Network coverage and stability in the station and train
			D15: Availability and maintenance of health and emergency medical facilities at station and train
		C2: Station and train service environment	D16: Air quality, lighting, and temperature comfort on the high-speed train
			D17: Cleanliness of the high-speed rail station and train
			D18: Security order at the high-speed rail station and train
		C3: Overall competence of service personnel	D19: Station entry security check and ticket verification service
			D20: High-speed railway station waiting and boarding service
			D21: Ticket checking and disturbance level on the high-speed train
			D22: Availability of train staff
			D23: Attitude and problem-solving capability of station and train staff
			D24: Services for vulnerable groups such as the elderly, disabled, pregnant, etc., at the station
	B2: Expected quality	C4: Overall expectations	D25: Pre-boarding expectations of service quality
	B3: Perceived value	C5: Perceived overall value	D26: Overall satisfaction with station and train services (value for money satisfaction level)

This study uses the weighted average method for calculating membership levels to conduct a quantitative analysis of the final evaluation results.

$$F = VB^t = (v_1, v_2, \cdots v_n) \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_n \end{bmatrix} \qquad (8)$$

In this study's comprehensive evaluation, each indicator is assessed on a five-point scale: $V = [V_1, V_2, V_3, V_4, V_5]$ = [very dissatisfied, dissatisfied, neutral, satisfied, very satisfied], with values assigned as $V = [1, 2, 3, 4, 5]$. Passengers individually score these indicators, and the frequency of each rating is recorded. The degree of membership for each indicator to a specific appraisal level is determined by the proportion of scores for that level, forming a fuzzy comprehensive evaluation matrix.

This study also uses SPSSAU Project (2024) statistical analysis software to streamline calculations and derive satisfaction values.

5. RESULT AND DISCUSSION

The objective of this study is to construct passenger satisfaction measurement system for JBHSR, explore and assess the current state of passenger services on JBHSR,

TABLE V: SUMMARY OF WEIGHT

1st level	2nd level	3rd level	4th level	Weight	Global weight
A passenger satisfaction	B1: Perceived quality (weight: 0.6737)	C1: Station and train service functions (weight: 0.7223)	D1: Accessibility of public transportation to and from the high-speed rail station	0.0378	0.0184
			D2: Ease of buying tickets	0.0628	0.0306
			D3: Facilities for car parking	0.0558	0.0272
			D4: Station internal signage	0.0377	0.0183
			D5: Punctuality of the high-speed Train	0.1318	0.0641
			D6: Overall completeness and convenience of station and train facilities	0.0739	0.0360
			D7: Convenience and simplification of transfer process, especially for feeder line at Padalarang	0.1103	0.0537
			D8: High-speed train carriage and seating arrangements	0.0370	0.0180
			D9: Provision of drinking water on the high-speed train	0.0212	0.0103
			D10: Variety, taste, quality, and pricing of meals and products sold at the station and on the train	0.0191	0.0093
			D11: Warning and safety notices at high-risk areas in the high-speed rail station and train	0.1477	0.0719
			D12: Comfort of the seating areas in the station and train	0.0389	0.0189
			D13: Timeliness and accuracy of train operation information	0.0763	0.0371
			D14: Network coverage and stability in the station and train	0.0767	0.0373
			D15: Availability and maintenance of health and emergency medical facilities at station and train	0.0729	0.0355
		C2: Station and train service environment (weight: 0.1857)	D16: Air quality, lighting, and temperature comfort on the high-speed train	0.3046	0.0381
			D17: Cleanliness of the high-speed rail station and train	0.1731	0.0217
			D18: Security order at the high-speed rail station and train	0.5223	0.0653
		C3: Overall competence of service personnel (weight: 0.0920)	D19: Station entry security check and ticket verification service	0.1295	0.0080
			D20: High-speed railway station waiting and boarding service	0.1321	0.0082
			D21: Ticket checking and disturbance level on the high-speed train	0.0888	0.0055
			D22: Availability of train staff	0.1726	0.0107
			D23: Attitude and problem-solving capability of station and train staff	0.3010	0.0187
			D24: Services for vulnerable groups such as the elderly, disabled, pregnant, etc., at the station	0.1760	0.0109
	B2: Expected quality (weight: 0.0810)	C4: Overall expectations (weight: 1)	D25: Pre-boarding expectations of service quality	1	0.0810
	B3: Perceived value (weight: 0.2457)	C5: Perceived overall value (weight: 1)	D26: Overall satisfaction with station and train services (value for money satisfaction level)	1	0.2457

identify existing gaps and issues, and propose strategies to address them. To gain a deeper understanding of the primary concerns among passengers, this study collects data through interviews, questionnaires, and focus group discussions. Advanced analytical tools and techniques, including AHP and FCE, are applied to assess and optimize passenger service experiences in a data-supported manner. Using IPA, the study identifies the importance of service attributes and passenger satisfaction levels and establishes priorities for improvement.

TABLE VI: QUESTIONERS RESULT

Indicator	Very satisfied	Satisfied	Neutral	Dissatisfied	Very dissatisfied
D1	99	166	97	45	8
D2	107	187	78	31	12
D3	64	146	174	19	12
D4	74	224	90	13	14
D5	178	191	38	0	8
D6	116	193	83	11	12
D7	78	175	128	18	16
D8	78	224	84	29	0
D9	33	105	213	44	20
D10	31	124	215	37	8
D11	54	224	125	8	4
D12	77	247	76	15	0
D13	106	212	84	5	8
D14	57	192	129	23	14
D15	40	181	176	18	0
D16	114	194	95	12	0
D17	155	195	61	4	0
D18	135	187	80	13	0
D19	59	263	69	24	0
D20	72	255	72	8	8
D21	64	220	123	8	0
D22	56	233	110	12	4
D23	76	202	125	4	8
D24	102	163	133	17	0
D25	91	224	99	1	0
D26	97	187	91	32	8

5.1. Passenger Satisfaction Evaluation Indicator System

In the process of constructing an evaluation system for JBHSR passenger service satisfaction, this study analyses the selection of evaluation indicators from existing literature on the subject. By synthesizing the characteristics and requirements in selecting indicators, the evaluation system constructed in this study is presented in Table IV.

5.2. The Weight of Evaluation Indicators

Based on the data collected from the pairwise comparison of the evaluation indicators, where each expert was asked to make a pairwise comparison of two indicators at the same level.

The weights of these twenty-six indicators, calculated from these comparisons, are shown in Table V.

5.3. Passenger Satisfaction Degree

Once the weights of the indicators were determined, the next step involved calculating the satisfaction scores for each indicator. The author collected satisfaction evaluations from passengers on twenty-six indicators by distributing questionnaires at various stations, which yielded 415 valid responses. Below, the statistical results of the survey from these 415 passengers are presented in Table VI.

Using the FCE method, the satisfaction degree for each indicator is calculated at each level, facilitating a comprehensive analysis of overall passenger satisfaction with HSR services. From the calculation, the overall passenger satisfaction degree for the JBHSR is 3.855, which indicates that passengers rate the overall service quality between "neutral" and "satisfied."

The summary of passenger satisfaction ratings for the twenty-six fourth-level indicators is presented in Table VII.

5.4. Importance-Performance Analysis

Since the third-level indicators—specifically, 'Pre-boarding expectations of service quality' and 'Overall satisfaction with station and train services'—directly influence the fourth-level indicators 'overall expectations' and 'perceived value' respectively, and are each 100% influential, they do not require further discussion in this section.

The weights of the twenty-four key service indicators are synthesized and normalized to determine their overall importance and satisfaction levels. The results are displayed in Table VIII.

Based on the table data, satisfaction and importance values for each indicator are plotted on a coordinate system. The axes are divided into four quadrants by average satisfaction (3.8055) and average importance (0.0417): 'Keep up the Good Work,' 'Concentrate Here,' 'Low Priority,' and 'Possible Overkill.' Each quadrant represents different levels of importance and satisfaction. Fig. 4 shows the twenty-four HSR service items in their respective quadrants.

Indicators in the top-right quadrant "Keep Up the Good Work" zone are marked by both high satisfaction and importance. These factors are highly valued and considered strengths that need to be maintained and further enhanced. The JBHSR features six indicators in this zone: D2, D6, D16, D18, and D5.

Indicators in the top-left quadrant "Concentrate Here" zone are crucial due to their high importance but currently

TABLE VII: Summary of Satisfaction Degree on 4ᵀᴴ Level

Indicators	Satisfaction degree
D1: Accessibility of public transportation to and from the high-speed rail station	3.7301
D2: Ease of buying tickets	3.8337
D3: Facilities for car parking	3.5566
D4: Station internal signage	3.7976
D5: Punctuality of the high-speed Train	4.2795
D6: Overall completeness and convenience of station and train facilities	3.9398
D7: Convenience and simplification of transfer process, especially for feeder line at Padalarang	3.6771
D8: High-speed train carriage and seating arrangements	3.8458
D9: Provision of drinking water on the high-speed train	3.2096
D10: Variety, taste, quality, and pricing of meals and products sold at the station and on the train	3.3205
D11: Warning and safety notices at high-risk areas in the high-speed rail station and train	3.7614
D12: Comfort of the seating areas in the station and train	3.9301
D13: Timeliness and accuracy of train operation information	3.9711
D14: Network coverage and stability in the station and train	3.6145
D15: Availability and maintenance of health and emergency medical facilities at station and train	3.5855
D16: Air quality, lighting, and temperature comfort on the high-speed train	3.9880
D17: Cleanliness of the high-speed rail station and train	4.2072
D18: Security order at the high-speed rail station and train	4.0699
D19: Station entry security check and ticket verification service	3.8602
D20: High-speed railway station waiting and boarding service	3.9036
D21: Ticket checking and disturbance level on the high-speed train	3.8193
D22: Availability of train staff	3.7831
D23: Attitude and problem-solving capability of station and train staff	3.8048
D24: Services for vulnerable groups such as the elderly, disabled, pregnant, etc., at the station	3.8434
D25: Pre-boarding expectations of service quality	3.9759
D26: Overall satisfaction with station and train services (value for money satisfaction level)	3.8024

TABLE VIII: Summary of Satisfaction Degree on 4ᵀᴴ Level

Indicators	Importance	Passenger satisfaction degree
D1: Accessibility of public transportation to and from the high-speed rail station	0.0273	3.7301
D2: Ease of buying tickets	0.0454	3.8337
D3: Facilities for car parking	0.0403	3.5566
D4: Station internal signage	0.0272	3.7976
D5: Punctuality of the high-speed Train	0.0952	4.2795
D6: Overall completeness and convenience of station and train facilities	0.0534	3.9398
D7: Convenience and simplification of transfer process, especially for feeder line at Padalarang	0.0797	3.6771
D8: High-speed train carriage and seating arrangements	0.0267	3.8458
D9: Provision of drinking water on the high-speed train	0.0153	3.2096
D10: Variety, taste, quality, and pricing of meals and products sold at the station and on the train	0.0138	3.3205
D11: Warning and safety notices at high-risk areas in the high-speed rail station and train	0.1067	3.7614
D12: Comfort of the seating areas in the station and train	0.0281	3.9301
D13: Timeliness and accuracy of train operation information	0.0551	3.9711
D14: Network coverage and stability in the station and train	0.0554	3.6145
D15: Availability and maintenance of health and emergency medical facilities at station and train	0.0527	3.5855
D16: Air quality, lighting, and temperature comfort on the high-speed train	0.0566	3.9880
D17: Cleanliness of the high-speed rail station and train	0.0321	4.2072
D18: Security order at the high-speed rail station and train	0.0970	4.0699
D19: Station entry security check and ticket verification service	0.0119	3.8602
D20: High-speed railway station waiting and boarding service	0.0122	3.9036
D21: Ticket checking and disturbance level on the high-speed train	0.0082	3.8193
D22: Availability of train staff	0.0159	3.7831
D23: Attitude and problem-solving capability of station and train staff	0.0277	3.8048
D24: Services for vulnerable groups such as the elderly, disabled, pregnant, etc., at the station	0.0162	3.8434

have low passenger satisfaction. Given their significance, the railway company should prioritize addressing and enhancing these critical areas. The JBHSR has five indicators in this zone: D14, D15, D7, D11, and D3.

Indicators in the bottom-left quadrant "Low Priority" zone, are not currently of utmost importance, and while satisfaction is low, they do not necessitate immediate action. However, these indicators could potentially shift
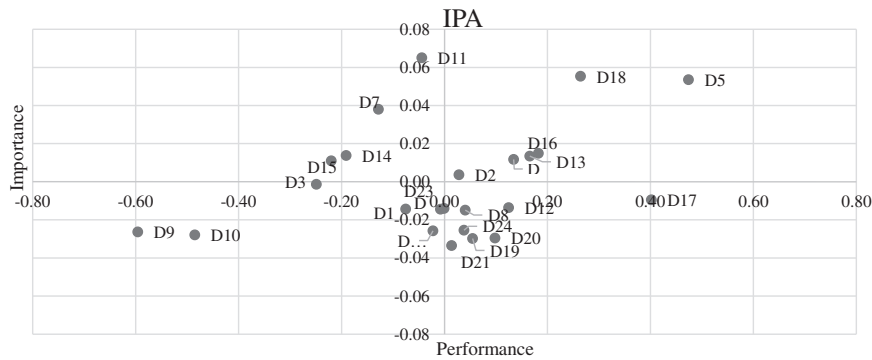
Fig. 4. Importance performance analysis.

TABLE IX: IMPROVEMENT RECOMMENDATION

Indicator	Current situation	Benchmark	Recommendation
D14: Network coverage and stability	The JBHSR stations and trains lack free Wi-Fi. Signal stability is compromised at high speeds and in tunnels	Wi-Fi is commonly available in HSR stations and trains in Japan and Europe, with varying accessibility features	Provide free Wi-Fi at stations and on trains, with ad integration during the login process to boost non-farebox revenue
D15: Health and emergency medical facilities	First aid stations are present, but there's low passenger awareness of these facilities	HSR in China, Japan, and Europe use clear signage and digital information to promote awareness of emergency facilities	Update the KCIC website and Whoosh app with detailed emergency facility info, and use broadcast announcements for regular reminders
D7: Transfer process	Transfer times at Padalarang station are tight, with inadequate escalator and elevator access, leading to congestion	Stations like Tokyo Station and Gare du Nord have multiple escalators/elevators and clear signage to facilitate quick transfers	Increase escalators and elevators, improve signage for easier navigation, and optimize train schedules to allow longer transfer times
D11: Warnings and alerts at dangerous locations	Adequate warning signs and emergency equipment are present but not sufficiently prominent or well-promoted	Stations in Japan and China, and Germany's HSR system, employ extensive safety signage, monitoring, and regular safety drills	Increase visibility of warning and emergency signs, and organize regular safety drills for both staff and passengers
D3: Station parking facilities High Speed Rail (n.d.)	Limited parking capacity at some stations, with inadequate public transport links exacerbating the issue	Hong Kong and South Korea offer parking reservation services and "park and ride" discounts at HSR stations	Expand parking capacity with government help, introduce a parking reservation system, and optimize public transport connections to stations

into "Concentrate Here" zone if not managed adequately, so they should not be overlooked. The JBHSR has six indicators in this zone: D9, D10, D22, D23, D1, and D4.

Indicators in the bottom-right quadrant "Possible Overkill" zone, are characterized by high satisfaction but are not considered the most critical factors currently. From a resource optimization perspective, the HSR operator could consider reallocating resources from these indicators. However, this approach should be executed cautiously to ensure these areas continue to function effectively. JBHSR has seven indicators in this zone: D19, D20, D21, D8, D12, D24, and D7.

6. CONCLUSIONS

The main conclusions of this study are as follows:

1. A passenger satisfaction evaluation system was constructed based on the complete set of HSR service experiences, including ticket purchase, station entry, waiting, boarding, and alighting, to measure passenger satisfaction.

2. A relatively reasonable passenger satisfaction survey questionnaire for HSR services was designed to collect passenger opinions. Through data analysis and calculation, quantitative results of passengers' overall evaluation of HSR services were obtained.

3. This study analyzes the survey results, employing the IPA method to identify HSR service items located in the 'Concentrate Here' and 'Low Priority' quadrants.

4. Drawing on passengers' actual travel experiences, the study proposes new measures and perspectives to effectively enhance passenger satisfaction.

7. RECOMMENDATION

Based on the findings and analysis, the following simplified recommendations are proposed to improve passenger service satisfaction, especially for indicators located in the top-left quadrant "Concentrate Here" zone (Table IX).

Conflict of Interest

The authors declare that they do not have any conflict of interest.

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