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| RESEARCH ARTICLE

Translating Passenger-Perceived Safety Quality into Operational Safety Priorities: Study of an Indonesian Urban Bus Service

Nabila Hafisha Rizka[1]✉, Rhaptyalyani Herno Della[2], and Melawaty Agustien[3]
[1,2,3]Sriwijaya University, Indonesia
Email : nabilahafishaiskandar@gmail.com[1], rhapty@unsri.ac.id[2], melawatyagustien@ft.unsri.ac.id[3]

Corresponding Author: Nabila Hafisha Rizka, **E-mail**: nabilahafishaiskandar@gmail.com

| ABSTRACT

Urban bus safety extends beyond accident records and vehicle condition, since passengers' safety experiences during access, waiting, boarding, travelling and alighting also play an important role. The objective of this study is to develop an SQFD method that bridges the gap between the passenger-perceived safety quality and operational hazard priorities in Teman Bus Corridor 5: Palembang, Indonesia. Several SERVQUAL-based safety attributes were formed, and expectations, perceived safety conditions, and service gaps were measured from the data collected from 392 passengers. The operational-hazard indicators came from observations in the field, data that existed in the transport-safety literature at the time, input operators, and historical operational records. Passenger safety indicators were treated as WHATs, while operational hazard indicators HOWs in the House of Quality framework. A total of 17 drivers evaluated A total of 17 drivers assessed the relationships between passenger-side safety indicators and operational hazard-event indicators, while 6 operators examined relationships among operational indicators. Estimated safety gaps were negative in all attributes, but most so in boarding and alighting safety, attention to vulnerable passengers and personal security. Passenger overcrowding, component failure during operation and stop or access were the greatest operational concerns. These findings show that passenger-perceived safety deficiencies should not be treated merely as service complaints, but should be translated into operational hazard-event priorities through a structured SQFD framework. The study provides an indicator-based decision-support approach for improving safety management in road-based urban bus services.

| KEYWORDS

Safety quality function deployment; passenger-perceived safety; operational safety priorities; urban bus service; house of quality; indonesia

| ARTICLE INFORMATION

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1. Introduction

Urban public transport safety is not confined to avoiding accidents or complying with regulations. It is also an essential requirement for passenger trust, perceived service quality, and the use of public transport. Safety in urban bus services happens throughout the passenger journey from access to stops, waiting for a bus, boarding the bus, travelling onboard the bus and lastly alighting. New studies have also shown that both perceived safety and safety-related service quality will affect passenger satisfaction, attitude and sustainable ridership (Agrawal et al., 2025; Chau et al., 2024; Choi et al., 2025; Sogbe Susilawati S. & Pin, 2025). On the other hand, passenger-based safety assessments typically continue in a diagnostic manner by measuring satisfaction levels or perceived service conditions or gaps between expected experience and actual experience. While these evaluations provide a strategic metric for which safety attributes passengers see as under-delivering, they do not necessarily tell service providers what operational hazards, risk events or safety-control priorities that need to be addressed.
Such a limitation seems especially salient for road-based urban bus services since passenger safety is influenced by various operational and environmental conditions. They can involve safety risks around stop and access environments, during mixed

traffic interactions, at boarding and alighting points, inside crowded vehicles or via the condition of the vehicle, driver behavior, lack of service reliability, personal security threats and emergency preparedness. Research on access to bus stops has shown that their use and surrounding environments are risk spaces, responding to the behavior of pedestrians and road users, characteristics of stops, and traffic conditions. (Yendra Haworth N. et al. 2024) Several other studies on bus and road transport safety have similarly found that behavioral factors at the level of the operator (or driver), condition of vehicle, component failure, conflict situations, euphemistic general conditions affecting roads and crowding of vehicles with passengers also contribute to operational risks regarding safety (Adanu et al., 2024; Jia et al., 2022; Márquez Alfonso A J. V. & Poveda, 2019; Sha Hu J. Zhang Q. & Wang, 2022; Wang & Zacharias, 2020). Thus, passenger-perceived safety problems should not only be considered service complaints but should be related to operational hazard sources and risk events that operators can monitor, manage or eliminate. One stream is related to the evaluation of passenger-based public transport, which aims at identifying safety-related service deficiencies through perceived safety, service quality, satisfaction, expectation perception gaps and user attitudes (Agrawal et al., 2025; De Oña & De Oña, 2015; Nguyen-Phuoc Phuong Tran A. T. Nguyen T. Van Le P. T. & Su, 2021). From this perspective, safety is captured from the user experience of safety, but does not adequately inform how deficiencies perceived by passengers might be reflected as priorities on operational safety. The second stream relates to operational safety and risk assessment, which includes driver behavior and stop accessibility; passenger safety on board the vehicle; road conditions; traffic conflicts with other vehicles or pedestrians; or any other sources of technical or environmental hazards (Jeong et al., 2022). This view is useful for pinpointing where in the transport system, risks exist, however it tells us little of how do those correlate to safety features that passengers notice and put emphasis on. Thus, public transport safety evaluation is still not equipped with a structured mechanism connecting passenger-side traffic safety quality indicators to operational hazard-event indicators.

The key advantage of using Quality Function Deployment (QFD) as a basis to solve this issue is that it translates the voice of users into technical or operational priorities by means of House of Quality (Akao, 2019). In service-quality research, SERVQUAL and expectation–perception gap model have been established in multiple studies to capture where the gap between user expectation and perceived service performance exist-based on residual calculations (Parasuraman Zeithaml V. A. et al. 1985). In safety research, QFD has been adapted into methodologies such the House of Safety (Braglia et al., 2018), Safety Function Deployment (Dhalmahapatra et al., 2022) and Safety Quality Function Deployment (Yang Chin K. S. et al. 2018; Zhigerbayeva & Yang, 2021) to map safety requirements on hazards, risk events and control measures. QFD and SQFD are also employed to examine public transport service quality, using user requirements as the basis for technical priorities (Astuti et al., 2021), safety-management implementation choices (Shang. et al. 2022). While current applications have established a methodology for linking passenger-level perceived quality indicators of safety to operational hazard-event priorities in road-based urban bus services, However, existing QFD and SQFD applications in public transport have rarely provided a structured linkage between passenger-perceived safety quality indicators and operational hazard-event priorities in road-based urban bus services. Therefore, a methodological gap remains in translating passenger-side safety deficiencies into operational hazard-event priorities that can support safety management decisions.

Teman Bus Corridor 5 (TB.V) in Palembang, Indonesia is a salient empirical setting in which to explore this issue. As of November 2024, the service transitioned from large buses to microbuses in the same management structure operating from a similar base but working in mixed urban traffic. Amongst its focus during the 2021–2024 large-bus operating period, systematic records of Teman Bus Palembang's historical operational data covering traffic disruptions, road-condition conflicts, risky driving behavior and component damage or failure categorized 378 cases relevant to safety (bus-and-stopping-point risks) as follows. These records are not utilized to predict the current level of safety of the post-transition microbus fleet, they give additional context in identifying operational hazard-event categories within the service environment. The focus on fleet transition is because changes to vehicle size/capacity/operating conditions are likely to affect passenger-facing safety issues (e.g. crowding, boarding and alighting safety, movement space/accessibility of stops/proximity to surrounding traffic).

This study is thus conducted to design and apply an integrated Safety Quality Function Deployment approach for the operational hazard-event prioritisation based on passenger-perceived safety quality indicators in the Teman Bus Corridor 5 service. This study positions passenger-side safety quality indicators and operational hazard-event indicators into WHATs and HOWs respectively within the House of Quality. These assessments include passenger safety expectations, perceived conditions and safety quality gaps among passengers; driver and operator assessements of WHAT – HOW relationships and the inter-relationship amongst operational indicators. The novelty of this study is the coupling of SERVQUAL-based passenger safety evaluation with SQFD based operational hazard-event prioritisation in a road based urban bus environment. Theoretically, this study contributes to transport safety science by extending passenger-perceived safety quality from a service quality perspective into an operational safety prioritisation framework. It provides a conceptual linkage between subjective passenger safety perceptions and operational hazard-event indicators, thereby supporting a more integrated understanding of how perceived service quality gaps can be translated into actionable safety improvement priorities. The study thus offers an indicator-based decision-support framework to connect passenger-perceived service quality regarding safety with implementable operational safety priorities for urban bus services in the road environment.

2. Methodology

Research design and study context

This study applied a Safety Quality Function Deployment approach to link passenger-perceived safety quality indicators with operational hazard-event indicators in an Indonesian urban bus service. The empirical case was Teman Bus Corridor 5 in Palembang, Indonesia, a road-based urban public transport service operating in mixed traffic. The House of Quality was used as the main analytical framework, with passenger-side safety quality indicators positioned as WHATs and operational hazard-event indicators positioned as HOWs. The overall research workflow is presented in Figure 1.

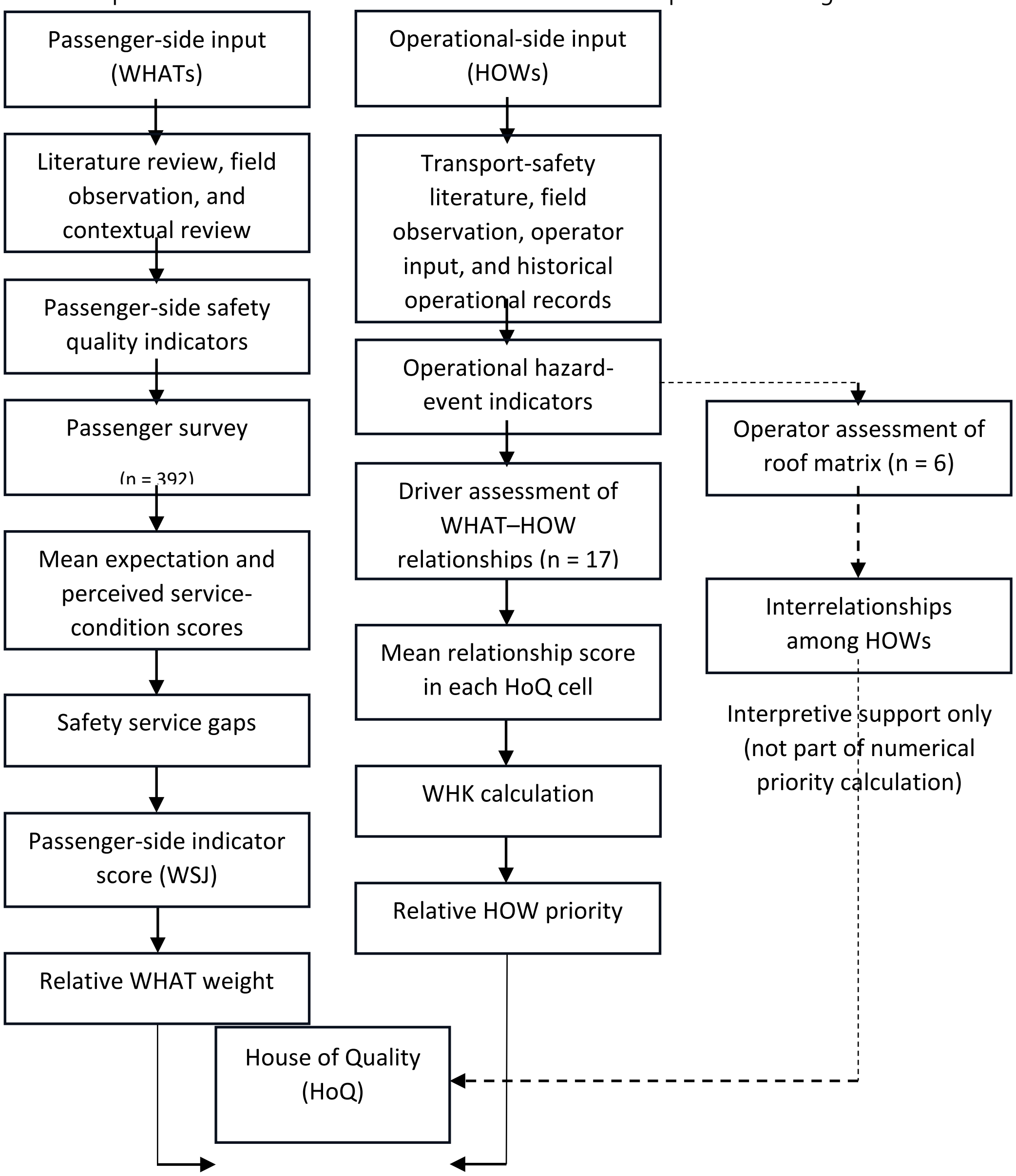


Figure 1. SQFD research workflow

This study conducts empirical research focused on Corridor 5. Its data collection period ran from September 2025 to February 2026, and a total of six categories of data sources were adopted: passenger surveys, driver assessments, operator assessments, field observations, existing literature, and historical operational records.

Each data source served a distinct analytical purpose. Passenger surveys were used to measure safety expectations, perceived service conditions, safety service gaps, and relative passenger-side indicator weights. Driver assessments were used to evaluate the relationships between passenger-side safety quality indicators and operational hazard-event indicators, while operator assessments were used only to interpret interrelationships among operational hazard-event indicators through the roof matrix. Respondents were selected using accidental sampling. The inclusion criteria were that respondents were users of Teman Bus Corridor 5, had experience using the service, and were willing to complete the questionnaire. Of 400 collected questionnaires, 392 valid responses were retained for analysis.

The expert respondents consisted of 17 active Teman Bus drivers and 6 operators, each with at least five years of operational experience. Drivers assessed the relationship between passenger-side indicators and operational hazard-event indicators because they have direct experience with service operation, passenger interaction, vehicle movement, traffic conditions, and field safety conditions. Operators assessed the roof matrix because they have practical knowledge of fleet management, service capacity, stopping points, operational disruptions, and safety-procedure implementation.

Historical operational records from the wider Teman Bus Palembang system were used as contextual grounding for the operational hazard-event indicators. The records covered the 2021–2024 large-bus operating period and included 378 safety-relevant operational cases. These records were used to support the contextual relevance of the hazard-event indicators and were not used to infer the current safety level of the post-transition microbus fleet.

Indicator operationalization

Two groups of indicators were operationalized in the House of Quality. The first group consisted of passenger-side safety quality indicators, which represented the WHATs. These indicators were adapted from SERVQUAL, public transport service-quality studies, and passenger-perceived safety literature. The SERVQUAL dimensions of tangibles, reliability, assurance, empathy, and responsiveness were used as the classification structure, while the selected indicators were limited to safety-related passenger experiences in road-based urban bus services. The final passenger-side indicators are presented in Table 1.

Table 1. Passenger-side safety quality indicators used as HoQ WHATs

Dimensions	Indicator	Description	References
Tangibles	Vehicle condition and operational fitness	The vehicle is physically and technically suitable to support safe passenger travel.	(Çelİk, 2024)
	Boarding and alighting safety	Boarding and alighting conditions reduce the risk of slipping, tripping, falling, or unsafe passenger movement.	(Suria et al., 2019)
Reliability	Service regularity	Regular service arrivals reduce waiting uncertainty and support safer passenger travel behavior.	(Chau et al., 2024b)
	Safe and stable driving	Vehicle speed, braking, maneuvering, and distance keeping support a safe and stable journey.	(Çelİk, 2024)
Assurance	Personal security	Passengers feel protected from disturbance, harassment, or other security threats during service use.	(Shang et al., 2022)
	Safety equipment availability	Safety equipment is available, visible, and functional when needed.	(Astuti et al., 2021; Shang et al., 2022; Wu et al., 2016)
Empathy	Driver courtesy and respect	Driver behavior supports passenger confidence, comfort, and perceived safety.	(Astuti et al., 2021)
	Attention to vulnerable passengers	The service accommodates passengers who may require additional protection or assistance.	(Astuti et al., 2021)
Responsiveness	Passenger assistance	Drivers or service personnel assist passengers who experience difficulties or safety-related needs.	(Astuti et al., 2021; Shang et al., 2022; Suria et al., 2019)
	Safety information and response	Drivers or service personnel provide clear information or responses during unsafe conditions, disruptions, or assistance needs.	(Astuti et al., 2021)

The second group consisted of operational hazard-event indicators, which represented the HOWs. These indicators were derived from transport-safety literature and contextualized using field observations, operator input, and screened historical operational records. The 378 historical cases were used only to support the contextual relevance of the operational indicators, not to measure the current safety level of the post-transition microbus fleet. The operational-side indicators are presented in Table 2.

Table 2. Operational hazard-event indicators used as HoQ HOWs

Category	Indicator	Description	References
Hazard source	Fleet roadworthiness	Vehicle condition and operational fitness may influence the likelihood of safety disturbances during service.	(Sam et al., 2018)
	Risky driving behavior	Unsafe speed, braking, maneuvering, or distance keeping may increase operational safety risk.	(Jiao et al., 2024)
	Stop and access risks	Stop locations, waiting areas, boarding and alighting points, visibility, surface conditions, and traffic exposure may affect passenger safety.	(Sha et al., 2022)
	Emergency readiness	The availability and readiness of safety equipment and emergency procedures affect the service's ability to respond to unsafe conditions.	(Shang et al., 2022)
Risk event	Component failure during operation	Technical or mechanical problems may disrupt operation and create safety risks for passengers or other road users.	(Adanu et al., 2024)
	Traffic disruption and road-condition conflict	Congestion, damaged roads, flooding, interaction with other vehicles, and traffic conflicts may affect operational safety.	(Mohamed et al., 2023)
	Passenger overcrowding	High passenger density may increase safety risks during waiting, boarding, alighting, and onboard movement.	(Shang et al., 2022)

In the HoQ structure, the passenger-side safety quality indicators in Table 1 were positioned as WHATs, while the operational hazard-event indicators in Table 2 were positioned as HOWs. Passenger-side indicators were used to assess expectations, perceived service conditions, safety gaps, and relative WHAT weights. Operational-side indicators were used in the driver-assessed WHAT–HOW relationship matrix and the calculation of HOW priorities.

Passenger assessment and safety service gaps

Passengers assessed each passenger-side safety quality indicator using two five-point Likert scales: expectation and perceived service condition. For the expectation scale, 1 indicated "very unimportant" and 5 indicated "very important." For the perceived service-condition scale, 1 indicated "very inappropriate" and 5 indicated "very appropriate."

For each passenger-side indicator j, the mean perceived service-condition score $\bar{K}_j$and mean expectation score $\bar{H}_j$were calculated from passenger response frequencies. The safety service gap was calculated as:

$$Gap_j = \bar{K}_j - \bar{H}_j$$

where Gap_j is the gap value of passenger-side safety quality indicator j, $\bar{K}_j$ is the mean perceived service-condition score of indicator j, and $\bar{H}_j$is the mean expectation score of indicator j. A negative gap indicates that the perceived service condition is below passenger expectation. For diagnostic ranking, the absolute value of the gap was used, with larger absolute values indicating greater passenger-perceived safety deficiencies. The initial weight of each passenger-side safety quality indicator was calculated as:

$$w_{sj} = \frac{\bar{K}_j}{\sum_{j=1}^{J} \bar{K}_j} x \, \bar{H}_j$$

where $w_{sj}$is the initial weight of passenger-side safety quality indicator j, $\bar{K}_j$is the mean perceived service-condition score of indicator j, $\bar{H}_j$is the mean expectation score of indicator j, and $J$is the number of passenger-side safety quality indicators.

The relative weight of each passenger-side safety quality indicator was then calculated as:

$$\bar{W}_{sj} = \frac{w_{sj}}{\sum_{j=1}^{J} w_{sj}}$$

where $\bar{W}_{sj}$is the relative weight of passenger-side safety quality indicator j, and $w_{sj}$is its initial weight. The gap values and relative WHAT weights were used to describe the passenger-side safety quality condition. They were not used as direct multipliers in the final calculation of operational hazard-event priorities.

HoQ relationship assessment, WHK calculation, and roof matrix

The WHAT–HOW relationship matrix was assessed by 17 drivers. Drivers evaluated the strength of relationship between each passenger-side safety quality indicator and each operational hazard-event indicator using a 0–9 scale. A score of 0 indicated no relationship, ≥1-4 indicated a weak relationship, ≥ 4- 7 indicated a moderate relationship, and > 7 - 9 indicated a strong relationship. In the HoQ visualization, weak relationships were marked with △, moderate relationships with ■, and strong relationships with •. These symbols were used only to improve visual readability; the numerical calculations were performed using the averaged driver scores.

The initial importance value of each operational hazard-event indicator was calculated by summing the mean relationship scores in each HOW column:

$$w_{hk_k} = \sum_{j=1}^{J} \bar{z}_{jk}$$

Where $w_{hk}$is the initial importance value of operational hazard-event indicator k, $\bar{Z}_{jk}$is the mean driver-assessed relationship score between passenger-side safety quality indicator j and operational hazard-event indicator k, and $J$is the number of passenger-side safety quality indicators.

The relative priority weight of each operational hazard-event indicator was then calculated as:

$$\bar{W}_{hk} = \frac{w_{hk}}{\sum_{k=1}^{K} w_{hk}}$$

Where $\bar{W}_{hk}$is the relative priority weight of operational hazard-event indicator k, $w_{hk}$is its initial importance value, and $K$is the number of operational hazard-event indicators. Thus, the final HOW priority was derived from the summed average driver-assessed relationship scores in each HOW column. The passenger-side relative WHAT weights and driver-based relative HOW priorities were both presented in the HoQ framework, but the HOW priority was not calculated by multiplying WHAT weights with relationship scores.

The roof matrix was used to interpret interrelationships among operational hazard-event indicators. Six operators assessed HOW–HOW relationships using a five-point scale, where 5 indicated a very strong positive relationship, 4 indicated a positive relationship, 3 indicated a neutral relationship, 2 indicated a negative relationship, and 1 indicated a very strong negative relationship. The roof-matrix score for each pair of operational hazard-event indicators was calculated using the median operator assessment:

R_{kl} = median ($q_{kl1}, y_{kl2,\ldots\ldots}y_{klO}$)

where $R_{kl}$is the roof-matrix score between operational hazard-event indicators $k$and l, $q_{klo}$is the score assigned by operator o, and $O$is the number of operator assessors. The roof matrix was used only for interpretive purposes to identify interrelationships among HOWs and did not affect the numerical calculation of HOW priorities.

Validity, reliability, and methodological controls

The passenger questionnaire was tested for item validity and internal consistency before the main analysis. Item validity was assessed using item-total Pearson correlation at a 5% significance level, with an r-table value of 0.0991. All items exceeded this threshold. The item-total correlation ranged from 0.571 to 0.920 for the expectation scale and from 0.247 to 0.832 for the perceived service-condition scale. Internal consistency was assessed using Cronbach's alpha, with values of 0.931 for the expectation scale and 0.830 for the perceived service-condition scale.

Content validity was supported through review by two academics and one representative from the Ministry of Transportation. The review examined indicator clarity, content relevance, contextual suitability for the Teman Bus service, and interpretation of the scoring scales. Methodological controls included collecting passenger data across different locations and service periods, averaging driver assessments across 17 respondents, and using median operator scores for the roof matrix.

The main methodological limitations are accidental passenger sampling, expert-based relationship scoring, and the use of historical operational records as contextual evidence rather than current post-transition safety-performance data. Therefore, the findings should be interpreted as an indicator-based operational safety prioritization for the Teman Bus Corridor 5 context rather than as a statistically representative safety-performance assessment of all Indonesian urban bus services.

3. Results and Discussion

Respondent and expert profiles

A total of 400 passenger questionnaires were collected from users of the Teman Bus Corridor 5 service. After checking response completeness and consistency, 392 valid questionnaires were retained for analysis. In addition, 17 drivers and 6 operators were involved as expert respondents in the HoQ assessment.

Table 3. Profile of passenger respondents

Variables	Category	Frequency	Percentage (%)
Gender	Male	93	23.72
	Female	299	76.28
Age	<17 years	12	3.06
	18–25 years	147	37.50
	26–40 years	100	25.51
	41–55 years	100	25.51
	>55 years	33	8.42
Occupation	College student	98	25.00
	Housewife	65	16.58
	Private worker	94	23.98
	Civil servant	47	11.99
	Self-employed	25	6.38
	Other	63	16.07
Education	Elementary/junior high school	33	8.42
	High school/vocational high school	152	38.78
	Diploma	68	17.35
	Bachelor's degree	135	34.44
	Master's degree	4	1.02
Duration of using Teman Bus	<1 month	15	3.83
	1–3 months	76	19.39
	4–6 months	99	25.26
	7-9 7–9 months	85	21.68
	>9 months	117	29.85
Safety-related incident experience	Ever	53	13.52
	Never	339	86.48

As shown in Table 3, respondents were predominantly female, accounting for 76.28% of the sample. The largest age group was 18–25 years, representing 37.50% of respondents, followed by the 26–40 and 41–55 age groups, each accounting for 25.51%. In terms of occupation, college students represented the largest group at 25.00%, followed by private workers at 23.98% and housewives at 16.58%. Most respondents had used Teman Bus for at least four months, indicating that the sample largely consisted of users with repeated service experience. In addition, 86.48% of respondents reported having experienced safety-related conditions or events during service use. This high self-reported exposure strengthens the relevance of passenger safety perception in the analysis, although it should be interpreted as passenger-reported experience rather than formal incident data.

Table 4. Expert respondents involved in the HoQ analysis

Expert group	Role in analysis	Number of respondents	Relevant characteristics
Drivers	WHAT–HOW relationship matrix assessment	17	Active drivers with direct experience of daily operations and field safety conditions
Operators	Roof matrix assessment	6	Personnel involved in operational management and service safety implementation

This study analyzed the interviewed experts using the House of Quality (HoQ) compiled in Table 4, and clearly divided assessment responsibilities into two categories: drivers assess the correlation between passenger-side safety quality indicators and operational hazard events, while operational staff assess the internal correlations between operational indicators within the roof matrix. This division of labor aligns with the methodological design of this study and the general rules of the field.

Passenger safety service gaps

For each passenger safety quality indicator, this study calculated the difference between the average perceived score and the average expected score to obtain the service gap. The results are presented in Table 5. The gaps for all indicators are negative, and the safety conditions perceived by passengers all fell short of expectations.

Table 5. Passenger safety service gaps

Passenger safety attribute	Mean expectation	Mean perceived condition	Gap value	Gap rank
Vehicle condition and operational fitness	4.972	3.390	−1.582	5
Boarding and alighting safety	4.992	3.166	−1.827	1
Service regularity	4.977	3.388	−1.589	4
Safe and stable driving	4.962	3.620	−1.342	7
Personal security	4.982	3.367	−1.615	3
Safety equipment availability	4.967	3.564	−1.403	6
Driver courtesy and respect	4.952	3.653	−1.298	8
Attention to vulnerable passengers	4.987	3.327	−1.661	2
Passenger assistance	4.890	4.196	−0.694	10
Safety information and response	4.941	4.158	−0.783	9

Note: This study first defines the calculation rule for the core indicator gap: gap is calculated as passengers' perceived service status minus their expected service

value. The gap ranked 1st in absolute value corresponds to the largest negative gap. The top three negative gaps measured in this study are: boarding and alighting safety, -1.827; attention to vulnerable passengers, -1.661; and personal safety, -1.615. The core defects perceived by passengers are concentrated in travel safety-related conditions, and the gap in boarding and alighting safety also extends to risks at transitional nodes such as stop zones. The gap for attention to vulnerable passengers indicates that users perceive insufficient accommodation or protection for passengers who may require additional assistance. Meanwhile, the gap for personal security suggests that safety perception also includes protection from disturbance, harassment, or other security threats during service use.

The smallest gaps were found for passenger assistance and safety information and response, with values of −0.694 and −0.783, respectively. Although both indicators still showed negative gaps, their perceived performance was closer to passenger expectations than other safety indicators. This suggests that assistance and communication-related aspects were relatively better perceived than access-related safety, personal security, and vulnerable-passenger protection.

Overall, the gap results provide the passenger-side diagnostic picture of safety quality. They show which safety indicators passengers perceive as most deficient, but they do not directly determine which operational hazard-event indicators should be prioritized. For this reason, the passenger-side results need to be interpreted together with the HoQ-based relationship assessment.

Passenger-side WHAT weights

After identifying the safety service gaps, the initial weight and relative weight of each passenger-side safety quality indicator were calculated. These weights represent the relative prominence of passenger-side indicators in the HoQ structure. They are not equivalent to the gap ranking and were not used as direct multipliers in calculating driver-based HOW priorities.

Table 6. Relative weights of passenger-side safety quality indicators as HoQ WHATs

Passenger safety attribute	Initial weight	Relative WHAT weight	WHAT rank
Vehicle condition and operational fitness	0.470	0.095	7
Boarding and alighting safety	0.441	0.089	10
Service regularity	0.471	0.095	6
Safe and stable driving	0.501	0.101	4
Personal security	0.468	0.094	8
Safety equipment availability	0.494	0.100	5
Driver courtesy and respect	0.505	0.102	3
Attention to vulnerable passengers	0.463	0.093	9
Passenger assistance	0.573	0.115	2
Safety information and response	0.573	0.116	1

Note: WHAT ranks indicate the relative weight order of passenger-side safety quality indicators in the HoQ structure, not the safety service-gap ranking.

As shown in Table 6, the highest relative WHAT weight was assigned to safety information and response, with a value of 0.116, followed by passenger assistance at 0.115 and driver courtesy and respect at 0.102. These findings indicate that communication, assistance, and driver interaction are prominent passenger-side indicators within the HoQ structure. In contrast, boarding and alighting safety, attention to vulnerable passengers, and personal security had lower WHAT weights despite showing larger negative gaps in Table 5.

This difference is important because the two measures serve different analytical purposes. The gap ranking identifies the largest mismatch between expectations and perceived service conditions, whereas the relative WHAT weight describes the prominence of passenger-side safety quality indicators based on the weighting procedure. Therefore, indicators with the largest perceived deficiencies do not necessarily receive the highest WHAT weights. This distinction supports the need for an indicator-based translation mechanism rather than directly treating passenger gap rankings as operational priority rankings.

Driver-based operational hazard-event priorities and roof-matrix interpretation

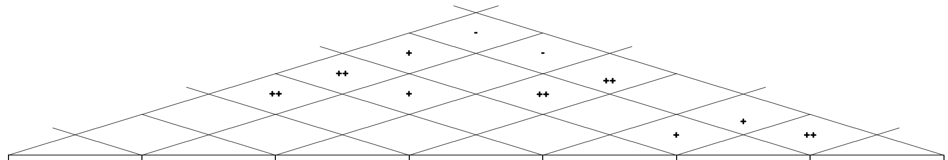
The operational-side priorities were derived from the driver-assessed WHAT–HOW relationship matrix. For each operational hazard-event indicator, the mean relationship scores across passenger-side safety quality indicators were summed to obtain the initial HOW weight, and the relative HOW priority was then calculated. These priorities reflect the strength of driver-assessed relationships between passenger-side safety quality indicators and operational hazard-event indicators.

Table 7. Driver-based HOW priorities of operational hazard-event indicators

Operational hazard-event indicator	Initial HOW weight	Relative HOW priority	HOW rank
Fleet roadworthiness	21.588	0.111	5
Risky driving behavior	11.647	0.060	7
Stop and access risks	32.176	0.166	3
Emergency readiness	21.529	0.111	6
Component failure during operation	34.529	0.178	2
Traffic disruption and road-condition conflict	32.059	0.165	4
Passenger overcrowding	40.353	0.208	1

Note: HOW priorities were calculated from summed average driver-assessed WHAT–HOW relationship scores. These priorities were not calculated by multiplying passenger-side WHAT weights with relationship scores.

As shown in Table 7, passenger overcrowding had the highest relative HOW priority, with a value of 0.208. This indicates that, from the driver-assessed relationship matrix, overcrowding was the operational hazard-event indicator most strongly connected to passenger-side safety quality indicators. Component failure during operation ranked second, with a relative priority of 0.178, followed by stop and access risks at 0.166 and traffic disruption and road-condition conflict at 0.165. Calculations from this study show that the relative priority of dangerous driving behaviors in public transport operation scenarios is only 0.060, the lowest value among all safety dimensions. This finding overturns the conventional view that operation safety only needs to focus on driver behavior. The core safety priorities of this study are concentrated on four dimensions: passenger density, vehicle technical reliability, station and access conditions, and interaction with the road traffic environment. Each dimension is analyzed and demonstrated based on the specific impact pathways of actual operation scenarios, and can directly support subsequent resource allocation decisions for safety management.



Relative Weight	Weight	Mean	Rank	Passenger safety \ Operational hazard-event	Fleet roadworthiness	Risky driving behavior	Stop and access risks	Emergency readiness	Component failure during operation	Traffic disruption and road condition conflict	Passanger overcrowding
0,095	0,470	3,390	7	Vehicle condition and operational fitness	● 8,71			■ 5,06	● 8,47		
0,089	0,441	3,166	10	Boarding and alighting safety	△ 3,71	△ 3,76	● 8,76		■ 4,41	■ 5,65	■ 6,59
0,095	0,471	3,388	6	Service regularity					● 8,12	● 7,88	● 7,35
0,101	0,501	3,620	4	Safe and stable driving	■ 6,24	● 7,88			△ 3,65	■ 6,06	
0,094	0,468	3,367	8	Personal security			● 8,12		△ 1,29	△ 1,59	△ 2,35
0,100	0,494	3,564	5	Safety equipment availability	△ 2,94			● 8,41			
0,102	0,505	3,653	3	Driver courstey and respect					△ 1,94	△ 2,24	■ 5,12
0,093	0,463	3,327	9	Attention to vulnerable pessangers			● 8,12			△ 2,24	■ 6,53
0,115	0,573	4,196	2	Passanger assistance			● 7,18			△ 1,29	■ 6,82
0,116	0,573	4,158	1	Safety information and response				● 8,06	■ 6,65	■ 5,12	■ 5,59
				Total Value	21,588	11,647	32,176	21,529	34,529	32,059	40,353
				Relative Weight	0,111	0,060	0,166	0,111	0,178	0,165	0,208
				Priority							

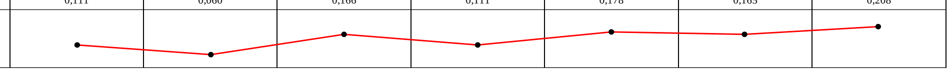


Figure 2 presents the first-stage HoQ results linking passenger-side safety quality indicators with operational hazard-event indicators. The discussion focuses on three main operational priorities derived from the HoQ results. First, passenger overcrowding had the highest priority and was related to multiple passenger-side safety dimensions, particularly boarding and alighting safety, attention to vulnerable passengers, passenger assistance, and personal security. This indicates that overcrowding may reduce safe movement space, increase difficulty during boarding and alighting, and limit the ability of service personnel to respond to passenger needs. Second, component failure during operation was strongly associated with vehicle condition and operational fitness, safety equipment availability, and emergency readiness. This finding shows that technical reliability affects both service continuity and passenger-perceived safety. Third, stop/access risks were closely connected with boarding and alighting safety and attention to vulnerable passengers, indicating that safety deficiencies are not limited to onboard travel but also occur during access, waiting, boarding, and alighting.

The roof matrix was then used to support interpretation of the interrelationships among operational hazard-event indicators. The results show that several operational hazards should not be managed separately. Passenger overcrowding is related to stop/access risks because high passenger density may intensify safety problems during waiting, boarding, and alighting. Similarly, fleet roadworthiness is related to component failure during operation because vehicle technical condition affects both operational continuity and passenger-perceived safety. Therefore, safety improvement should be coordinated across passenger-density management, preventive maintenance, stop/access safety, and traffic-related operational control.

4. Conclusion

This study developed and applied a Safety Quality Function Deployment approach to link passenger-perceived safety quality indicators with operational hazard-event priorities in Teman Bus Corridor 5, Palembang, Indonesia. By positioning passenger-side safety quality indicators as WHATs and operational hazard-event indicators as HOWs in the House of Quality, this study provides an indicator-based mechanism for translating passenger safety evaluation into operational safety priorities. The passenger survey results showed negative safety service gaps across all passenger-side indicators, indicating that perceived service conditions were still below passenger expectations. The largest gaps were found in boarding and alighting safety, attention to vulnerable passengers, and personal security. These findings suggest that passenger-perceived safety deficiencies are not limited to vehicle operation, but also occur during access, waiting, boarding, alighting, and personal-security experiences along the service journey.

The HoQ results showed that the highest operational hazard-event priorities were passenger overcrowding, component failure during operation, and stop/access risks. This indicates that passenger-side safety deficiencies should not be directly interpreted as operational priorities without a structured translation process. Passenger safety gaps identify what passengers perceive as underperforming, whereas the HoQ relationship assessment identifies the operational hazard-event indicators most strongly connected to passenger-side safety concerns.

The main contribution of this study lies in demonstrating how SQFD can connect passenger voice, safety service gaps, and operational hazard-event priorities in a road-based urban bus service. Practically, the findings suggest that operators should prioritize passenger-density management, preventive maintenance, and improvement of stop/access safety. These priorities should not be treated as isolated measures because the roof-matrix interpretation indicates interrelationships among passenger overcrowding, stop/access risks, fleet roadworthiness, component failure, and traffic-related operational conditions. Therefore, safety improvement should be coordinated across service capacity management, technical reliability, stop/access monitoring, and traffic-related operational control.

This study has several limitations. The empirical case was limited to one corridor, so the findings should be interpreted within the operational context of Teman Bus Corridor 5 and should not be generalized to all Indonesian urban bus services. The WHAT–HOW relationship matrix and roof matrix were based on expert assessments, while historical operational records were used only as contextual support rather than as direct evidence of current safety performance. Future studies may apply the SQFD framework to multiple corridors or urban contexts, integrate current operational safety data, compare alternative weighting methods, and evaluate whether the identified operational priorities lead to measurable safety improvements.

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