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Designing a Human-Centered Smart Counter for Transjakarta Using the House of Quality to Improve Service Inclusivity

Nova Pangastuti[1*], Olivia Oktariska Timbayo[1], Restu Pinasthika[2]

[1]Industrial Engineering Department, BINUS Online Learning, Bina Nusantara University, Indonesia

[2]Information System Department, BINUS Online Learning, Bina Nusantara University, Indonesia

*nova.pangastuti@binus.ac.id

Abstract. Jakarta's increasing vehicle usage has exacerbated air pollution, and as a result, the initiative to advance sustainable urban mobility and a target to achieve Net Zero Emissions by 2050. Nevertheless, public satisfaction with Transjakarta remains low due to inconsistent service quality and no real-time information for riders. This study puts forward the SmartCounter, a smart passenger-counting system developed by a Human-Centered Design (HCD) process with support from the SERVQUAL approach and House of Quality (HoQ) analysis. The research employs a mixed-method methodology using gap analysis, semi-structured interviews, and focus group discussions to comprehensively gather and convert user requirements into technical specifications. Critical parameters that are elicited from SERVQUAL then propel the Voice of Customer and subsequently get mapped to ranked technical needs with the help of the HoQ. SmartCounter utilizes cutting-edge sensing technology (Time-of-Flight or AI-integrated cameras) with onboard edge computing to enable automatic, real-time, and privacy-respecting passenger counting. The HoQ study prioritized three main technical imperatives: sensor accuracy (score 123), casing robustness (score 111), and real-time transmission (score 109). Other aspects include embedded processors (score 103), display units and operator dashboards (scores 84), and power systems (score 71). Overall, the SmartCounter actively addresses both passenger and operational needs, advancing Jakarta's goals towards a more sustainable, efficient, and inclusive urban transport system for Net Zero Emissions 2050.

Keywords: house of quality, human-centered design, servqual, smart counter, transjakarta

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1. Introduction

DKI Jakarta air pollution has reached alarming levels, which is driven principally by the exponential increase in the number of private vehicles. In the last few years, motorcycle vehicle ownership has grown 4.9% and passenger cars 7.01%, far exceeding the growth rate in the population of 0.92%. The number of private vehicles has doubled the population and today has surpassed over 20.2 million units. To this environmental issue of serious concern, the Government of DKI Jakarta has committed to be Net Zero Emissions by 2050, more precisely through adopting green technology within public transportations as part of its whole smart city strategy [1][2].

Though transportation is the largest energy-using sector in cities [3], however, mass transit infrastructures such as KRL and Transjakarta gain largely negative public perceptions. These feelings are also widely expressed in other public forums, like social media [4]. Although there have been several studies of customer satisfaction with the Transjakarta services, most have been perception-based assessments without trying to intervene in the system problems. In particular, research on Corridor 7 (KP. Rambutan – KP. Melayu) indicates that the quality of service possesses a strong positive correlation (75.4%) with user satisfaction [5], and this reaffirms the critical role of service quality in influencing public acceptance and confidence in public transportation.

Drawing from these observations, this study is established to develop a SmartCounter device using a Human-Centered Design (HCD) approach towards improving the inclusivity and service quality of Transjakarta. The research synthesizes user needs and experiences, identified through the SERVQUAL approach, in alignment with technical development following the House of Quality (HoQ) approach. By aligning technical solutions with authentic user requirements, this research seeks to develop actionable user-centric innovations to enhance accessibility and efficiency in public transport—hence contributing to Jakarta's overall sustainability and urban mobility objectives.

2. **Method**

This study employs a mixed-methods approach to create a more inclusive Transjakarta SmartCounter system through the combination of quantitative indicators of service quality and user-led design principles. This combination has been effectively applied to other user-initiated design interventions in the public transport context [6]. The research process consists of three successive stages: (1) service evaluation, (2) identification of user needs, and (3) technical translation using the House of Quality (HoQ). Data for this study are available at: https://doi.org/10.5281/zenodo.16019627.

2.1. SERVQUAL Analysis of Service

The first stage involves assessing the service quality of Transjakarta using the assistance of the SERVQUAL model, which measures five main dimensions of tangibles, reliability, responsiveness, assurance, and empathy. The survey instrument was adapted from the official annual report of PT Transportasi Jakarta. Discrepancy analysis was employed to measure differences between users' expectation and experience. Despite recent advances in electronic transit systems, SERVQUAL remains a robust and widespread tool to examine perception of service in public transportation [7].

2.2. Human-Centered Design Identification

Human-centered design identification is the second phase that attempts to seize more user insights through qualitative discovery. This was achieved through semi-structured interviews and focus group discussions (FGDs), with themes focusing on accessibility barriers, service inclusivity, and user experience. The HCD method, which combines FGDs with field visits, has been proven to work well in gaining user needs in designing public service systems [8][9]. Thematic analysis was used to group and synthesize the qualitative data into key user requirements in a nutshell. These were then compared against SERVQUAL outputs to develop a complete vision of user-focused priorities. Such combined approaches have been proven effective in the situation of rail and bus rapid transit [10].

2.3. Technical Design Based on House of Quality

The third stage saw the user requirements identified to be systematically translated into technical requirements through the House of Quality matrix, which is the initial step in the Quality Function Deployment (QFD) process. The relationship matrix was formulated where the "WHATs" (user requirements) were aligned with the "HOWs" (technical solutions), and both were ranked based on user importance and implement difficulty. This step allows for the transformation of qualitative findings into concrete technical solutions. Previous studies have proven that technical mapping with QFD is very effective in user-pull feature prioritization in smart urban mobility projects [11][12].

The outcome of this three-stage process is the first prototype of the SmartCounter, being adaptive, accessible, and responsive to both the operational requirements of Transjakarta and the requirements of its users. By the integration of quantitative service information and qualitative user perspectives, and their translation into technical design features, the research provides a rigorous and user-centered approach to the development of intelligent transportation solutions.

The work adopts a systematic methodological process with four major phases: (i) data collection, (ii) SHAP value-based feature selection, (iii) model development and hyperparameter tuning, and (iv) measurement of performance.

3. Result and discussion

3.1. Service Quality Assessment (SERVQUAL)

Transjakarta actively monitors service performance in the form of periodical evaluations conducted by internal organizations and the Ministry of Transportation, using tools such as the Mystery Shopper method. The evaluations comply with standards contained in annually reviewed agreements. However, the general performance of Transjakarta's Minimum Service Standards (SPM) experienced detrimental shifts in some areas of services, although it had an average achievement rate of 97.82% in 2022—at above the 95% benchmark. This drop is echoed in broader trends detailed in regional studies indicating service problems in Bus Rapid Transit (BRT) systems in cities in developing regions [13].

Table 1. Transjakarta Minimum Service Standards (SPM) by Service Type and Quarter in 2022

Service Type	Q1	Q2	Q3	Q4
BRT	99.00%	99.86%	99.55%	99.78%
BB BS	99.43%	96.03%	98.88%	97.33%
IBK	94.00%	94.63%	94.33%	96.51%
Transjakarta Cares	100.00%	99.19%	100.00%	100.00%
End Result	98.00%	97.19%	98.00%	98.10%
Average Performance				**97.82%**

Source: Annual Report of PT Transportasi Jakarta (2023)

More scrutiny of the BRT mode of service reveals some significant shortcomings. Its worst-performing indicators are inadequate air circulation facilities, inadequate access to service information, a lack of real-time arrivals and disruptions updates, inadequate lighting of bus stops, and inadequate assistance for smooth boarding and alighting. For example, many display screens in shelters were not functioning or presented incorrect data. Furthermore, fans or air circulation units were not operational even during working times. Though lighting standards (100 lux) were generally met, the Transportation Department continued to point out issues in some of the shelters. The need to improve real-time information systems is especially pressing with rising user expectations [14].

Table 2. Lowest-Performing Service Attributes in BRT (Transjakarta)

Rank	Service Attribute
1 (Lowest)	Inadequate air circulation support facilities
2	Insufficient service information provided to passengers
3	Lack of real-time updates on arrival schedules and service disruptions

4	Suboptimal lighting infrastructure at bus shelters
5	Inadequate boarding and alighting facilities for passengers

A perceptual mapping analysis was conducted to supplement the SERVQUAL findings. This study assessed users' opinions of several service properties on a three-year cycle. While the general user perception slightly improved from 8.19 in 2021 to 8.26 in 2022, there were some properties which decreased sharply. The perceived value of "Modern" decreased by 0.14, perhaps due to the introduction of an unknown payments system and integration tariff. Similarly, the "Timely and Accurate" factor decreased by 0.21, reflecting that users experienced delays and experienced low-frequency services. "Respect and Responsiveness" also decreased by 0.10, suggesting the need for better staff interaction and upkeep of the infrastructure [15].

Table 3. Perceptual Mapping of Transjakarta Service Attributes (2020–2022)

Attribute	2020	2021	2022	Gap
Safety	8.07	8.24	8.38	+0.17
Modernity	8.26	8.27	8.13	–0.14
Affordability	8.76	8.93	9.06	+0.30
Accessibility (Reachable)	8.10	8.13	8.16	+0.06
Timeliness & Accuracy	7.88	7.84	7.63	–0.25
Environmental Friendliness	8.23	8.21	8.26	+0.03
Respect & Responsiveness	8.30	8.29	8.19	–0.11

On the other hand, positive shifts were seen in many areas. The "Safety" attribute increased by 0.14 due to enhanced bus and shelter safety measures. The “Affordable” dimension rose by 0.13 following the government’s decision to maintain fare levels despite inflationary pressures. A slight improvement in “Reachability” (0.03) was also observed as several routes suspended during the COVID-19 pandemic were reinstated. Additionally, the “Eco-Friendly” perception grew by 0.05, supported by the gradual integration of electric buses in selected corridors. These findings confirm the critical need for user-informed innovations in service design and digital information systems [16] to guarantee and intensify public satisfaction.

3.2. Human-Centered Design

3.2.1. Inspiration

The inspiration phase deals with developing an understanding of the needs and issues behind the Transjakarta user statements. To reveal such insights, researchers conducted further field observations and interviews with users to allow deeper and contextualized understanding of user experiences. From this process, several recurring issues were discovered and developed into problem statements, which represent specific issues for passengers. They are framed in negative statements to direct the ideation phase.

Table 4. Problem Definitions Emerged in the Inspiration Phase of HCD

No	Problem Definition
1	Users report buses to be delayed and reach with low frequencies, thus having long waiting times.
2	Passengers frequently can't board approaching buses due to the fact that buses are packed and there is no room left.

3	Passenger population or estimated bus arrival time is never informed in real time.
4	Overcrowding onboard occurs excessively, which leads to discomfort, fatigue, and lower service satisfaction.
5	Passengers frequently make boarding choices with inadequate information, which results in uncertainty and dissatisfaction.

3.2.2. Ideation

In the ideation stage, researchers explored a range of potential solutions through a facilitated brainstorming session. This involved empathetic role-playing—standing in the user's shoes—as well as interactive sessions with actual users. This co-creative process enabled the exploration of novel ideas grounded in real-world pain points. The ideas that surfaced revolve around harnessing real-time information, intelligent systems, and integrated technologies to upgrade the passenger experience.

Table 5. Ideation Stage: Proposed Solutions for Enhancing Passenger Experience

No	Proposed Idea
1	**Sensor-based SmartCounter** – Utilizes infrared sensors or AI cameras to scan and count passengers boarding and exiting at every door of a bus automatically.
2	**Mobile App Integration** – Integrates the SmartCounter system with the official Transjakarta mobile app in an effort to display real-time bus occupancy using simple-to-comprehend color indicators (e.g., green, yellow, red).
3	**Digital Shelter Display** – Deploys digital display screens at stops to indicate actual-time information on passenger load for arriving buses, enhancing user visibility upon boarding.
4	**Tap-in/Tap-out System Integration** – Connects with installed ticketing systems in order to synchronize SmartCounter data and heighten data accuracy on boarding and alighting behavior.
5	**Push Notification Alerts** – Enables the mobile app to proactively alert on bus overcrowding status, allowing passengers to decide whether to board in advance.

After coming up with these ideas, the research team proceeded to structure the findings using the House of Quality (HoQ) matrix. The HoQ serves as the bridge between qualitative user demands (the "WHATs") and their corresponding technical solutions (the "HOWs"), offering a methodical process for ensuring design responses that fulfill user expectations.

3.3. House of Quality

3.3.1. Voice of Customer

Customer needs were arrived at through SERVQUAL surveys to develop the Voice of Customer (VoC), representing users' public transport service performance expectations. The inputs form the basis for design specifications of the SmartCounter system. The users' needs and their relative weightage are given below.

Table 6. Voice of Customer (User Needs and Prioritization)

No.	Voice of Customer (Customer Need)	Importance
1	Passenger boarding and alighting needs to be counted by the system accurately.	5
2	Sensors must have the capability to perform in dense and low-light conditions.	4

3	The device must update passenger count data in real time.	5
4	Data gathered must be readily accessible to passengers and system operators.	4
5	Passenger flow and movement in the bus should not be disrupted by device installation.	3
6	The system must be power-efficient and provide operational reliability.	3
7	The physical construction of the device should be compact, secure, and tamper-proof and resistant to damage.	3

3.3.2. Technical Responses

Technical solutions were derived from interview data to fulfill each user requirement that was identified. These solutions define the characteristics which the SmartCounter must possess. The following gives the details of the technical specifications. Smart technologies and embedded processing are central in enhancing public transportation services [17].

Table 7. Technical Requirements (HOWs) for SmartCounter Development

No.	Technical Requirement (HOWs)
A	Implementation of dual infrared sensor or AI camera module to identify passengers accurately.
B	B Integration of embedded processing unit (e.g., Raspberry Pi or ESP32) to execute data processing inside the device.
C	Ability to transmit data in real-time through GSM or Wi-Fi protocols (e.g., MQTT) to maintain continuous connectivity.
D	Compatibility of visual display unit (e.g., LED or OLED display) to present occupancy data to end users.
E	Web or mobile dashboard user interface design for system administrator monitoring of operation.
F	Vandal-resistant and compact enclosure design for ruggedness to meet requirements for use in busy public places.
G	Installation of an off-grid power supply system, including solar panels and battery backup, to provide use in off-grid locations.

3.3.3. Relationship Matrix and Technical Importance Rating

Relationship matrix displays the correlation of each user requirement (WHAT) and its respective technical solution (HOW), denoted as weak (∇), moderate (O), or strong (●). These correlations are graded on a scale to obtain a technical importance score, which is derived by multiplying the user importance level by the strength of the correlation. This method has been effective in other urban transport innovation studies [18].

Customer Requirements (Explicit and Implicit) \ Functional Requirements	Dual infrared sensor / AI camera module	Embedded processor (e.g., Raspberry Pi / ESP32)	Real-time data transmission (GSM/WiFi MQTT)	Integration with display unit (LED/OL	Mobile/web dashboard for operators	Enclosure design: compact, vandal-proof casing	Power supply (solar panel + battery backup)
The system must accurately count passengers boarding and exiting	●	●	○	▽	▽	○	▽
The sensor must work in crowded or dim lighting conditions	●	○	▽			○	▽
The device must update the count in real-time	○	○	●	○	○	▽	▽
The information must be visible to both users and operators	▽	▽	○	●	▽	▽	
The installation should not interfere with passenger flow	▽	▽	▽	▽	▽	●	○
The device should consume low power and be reliable	▽	○	○	▽	▽	▽	●
The design must be compact and secure	▽	▽	▽	▽	▽	●	○

Figure 1. Relationship Matrix Between Customer Needs and Technical Requirements

Max Relationship	9	9	9	9	3	9	9
Technical Importance Rating	403,7	337	337	240,7	122,2	344,4	218,5
Relative Weight	20%	17%	17%	12%	6%	17%	11%
Weight Chart							

Figure 2. Technical Importance Matrix for SmartCounter Development

The three highest technical priorities were determined from QFD analysis. The sensor part (IR/AI camera) ranked first with a score of 123 by emphasizing detection accuracy as the most significant. Casing design (111) came second, emphasizing compactness and ruggedness for heavy use applications. Real-time data transfer was ranked number three (109) on the scale of how vital it is to deliver occupancy details in a timely fashion. Other critical features include the embedded processor (103), display unit and operator dashboard (84 each), while the power supply system, although critical, had the lowest priority (71) at this point of development.

3.3.4. SmartCounter Device Design Concept

a. Device Description
The SmartCounter is an intelligent passenger counting device that integrates sensing technologies and edge computing [19] to perform in-real-time boarding and alighting passenger detection. It may be deployed with Time-of-Flight (ToF) sensors or AI cameras assisted by embedded processors that ensure rapid on-site processing of data, making available higher performance while protecting user privacy [20].
b. Device Objectives
The major goals of the SmartCounter are:
a) Monitor live passenger capacity on board.
b) Monitor boarding and alighting patterns to enable operational planning.
c) Prevent overcrowding in order to enhance safety and user comfort.

The unit is designed to be compact and mounted securely at bus entry points. Data is sent to a central server via GSM or Wi-Fi and displayed on a central dashboard. Inclusive visual display solutions are essential for ensuring usability across different passenger demographics [21].
c. SmartCounter Design
Figure 3 are the visual outputs of the SmartCounter design concept.

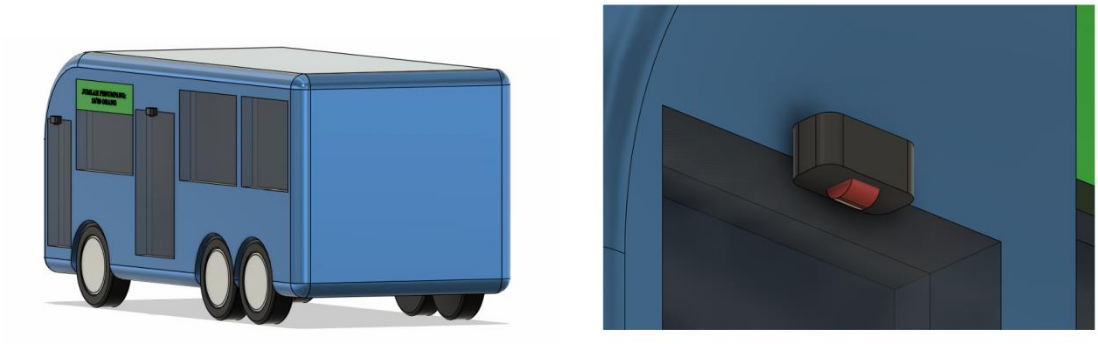

Figure 3. Visual outputs of the SmartCounter design concept

4. **Conclusion**

The research integrates the SERVQUAL model, Human-Centered Design (HCD), and the House of Quality (HoQ) methodology to design the SmartCounter for Transjakarta. The following device—powered by AI-based sensors and edge computing—successfully enables automated, accurate, and real-time detection of passenger boarding and alighting in evolving public transport environments. The process of development was deeply informed by the needs and emotions of users, as elicited through SERVQUAL surveys and HCD interviews. These needs, as the Voice of Customer, were also translated into technical specifications via the HoQ matrix.

Top development priorities are high-accuracy passenger counting sensors, a strong and secure device casing, and real-time data transmission. Other priorities include integration with embedded processors and ability to present data unambiguously via display units and operator dashboards. These design features reflect growing demands for inclusive, adaptive, and user-focused transportation technologies. Such innovations are key to accelerating the uptake of smart mobility and retrofitting mass transit systems in cities. Moreover, the SmartCounter contributes to Jakarta's overall drive towards Net Zero Emissions by 2050 through the support of data-driven optimization of public transport networks [22].

In sum, application of user-centric methodologies and casting service quality findings into technical specifications has helped to inform the development of pioneering instruments to enhance user experience and satisfaction [23]. The findings of this research are particularly relevant to designing inclusive technological solutions for public transport networks in developing countries. [24][25].

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