

Evaluation of Platform Level of Service Based on Acceptance Distance and User Perception at A Commuter Rail Station

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ABSTRACT

Rapid urbanisation and increasing passenger demand in metropolitan areas have intensified pressure on commuter rail station platforms, particularly in densely populated cities such as those within the Jakarta Metropolitan Area. This condition frequently leads to overcrowding, which affects passenger comfort, safety, and perceived service quality. However, existing Level of Service (LOS) frameworks primarily rely on technical density measures and do not fully capture user perceptions of crowding conditions. This study therefore aims to analyse passenger acceptance of platform crowding and determine the critical density threshold that reflects the transition between acceptable and unacceptable conditions. The research employs a stated preference survey involving 297 respondents at Depok Commuter Station, generating 2,970 observations. Data were analysed using binary logistic regression to model the relationship between passenger density and acceptance probability. The results show that passenger density significantly influences acceptance levels, with a negative relationship indicating that higher density reduces acceptance probability. The critical density was identified at 6.70 passengers/m², corresponding to an acceptance distance of 0.386 metres. These findings demonstrate a gap between theoretical LOS standards and actual passenger perceptions. In conclusion, integrating user perception into crowding evaluation provides a more accurate and human-centred assessment of platform service quality. The study contributes to transit planning by offering empirical thresholds for crowd management and station design improvements.

INTRODUCTION

Rapid urbanisation and increasing economic activity have intensified mobility demand in metropolitan areas worldwide. In the Jakarta Metropolitan Area (Jabodetabek), commuter rail services play a vital role in supporting daily travel due to their high carrying capacity, operational reliability, and ability to reduce dependence on private vehicles. As passenger demand continues to grow, railway stations face increasing pressure on their supporting facilities, particularly platforms, which function as waiting and boarding areas. High passenger concentration during peak periods frequently leads to crowding conditions that affect user comfort, safety, and overall service quality (Obsie et al., 2020; Xu et al., 2024).

Passenger density on railway platforms is widely recognised as one of the most important indicators in evaluating pedestrian and transit facility performance (Hänseler et al., 2016; Pu et al., 2022; Seriani et al., 2025). As density increases, the personal space available to each passenger decreases, potentially leading to discomfort, psychological stress, restricted movement, and reduced satisfaction with the travel experience (Fedujwar et al., 2024; Hensher et al., 2015). Previous studies have demonstrated that crowding significantly influences passenger comfort, travel behaviour, route choice, and perceived service quality (Shi et al., 2025). However, passengers' responses to crowding are not solely determined by physical conditions. Individual perceptions, travel experience, social characteristics, and familiarity with public transportation may also influence the degree to which crowding is considered acceptable (Lombardi & Ciceri, 2021; Rasoolimanesh et al., 2019; Wang & Zacharias, 2020).

To evaluate pedestrian and transit facilities, practitioners commonly employ the Level of Service (LOS) framework developed by Fruin. This approach classifies service quality according to passenger density and space per person, ranging from LOS A (very comfortable conditions) to LOS F (extremely crowded conditions) (Hänseler et al., 2016; Nikiforiadis et al., 2021). Although Fruin's classification has been extensively applied in transportation planning and facility design, the framework is fundamentally normative, as its threshold values are established on the basis of technical criteria rather than direct user perception (Andrikopoulou & Spyropoulou, n.d.; Raad & Burke, 2017). Consequently, the service levels defined by LOS classifications may not always reflect the actual comfort and acceptance levels experienced by passengers (Louviere et al., 2020; Rodrigue, 2020).

Recent studies have examined crowding effects in public transportation systems from behavioural, operational, and economic perspectives. Most previous research has focused on the impacts of crowding on comfort, travel behaviour, route choice, and passenger welfare. Nevertheless, studies specifically identifying user acceptance thresholds for platform crowding and linking these thresholds to LOS evaluation remain limited, particularly in the context of commuter railway stations in developing countries. Empirical approaches that translate passenger acceptance into measurable indicators for platform service assessment are also relatively scarce.

To address this research gap, this study evaluates passenger acceptance of varying platform crowding conditions at Depok Commuter Station, Indonesia, using a stated preference approach and binary logistic regression analysis. The study aims to identify the critical density threshold at which passengers are equally likely to accept or reject a crowding condition. The identified threshold is subsequently converted into an acceptance distance and compared with Fruin's LOS classification to examine the correspondence between normative standards and actual passenger perception. By integrating physical crowding indicators with user-based evaluation, this study contributes to the development of a more passenger-oriented approach for assessing platform service quality.

One of the most critical issues arising from this context is platform crowding at railway stations, where passengers wait and queue before boarding trains. High passenger density on platforms directly influences perceived comfort and service quality, as limited personal space can

lead to psychological stress, restricted movement, and decreased satisfaction. Although LOS frameworks such as Fruin's classification are widely used to assess pedestrian facility performance, these standards are based primarily on technical density measures rather than actual user perception, creating a potential mismatch between theoretical standards and real-world experiences.

Previous research has extensively examined crowding phenomena in public transportation systems from various perspectives. Cats et al. (2016) emphasised the role of passenger perception in crowding measurement, while Tirachini et al. (2017) analysed the behavioural and operational impacts of crowding in transit systems. De Ona et al. (2015) explored perceived service quality using structural equation modelling, and Fruin's (1971) foundational work established the standard LOS classification for pedestrian environments. Despite these contributions, most studies remain focused on general transit systems rather than platform-level acceptance behaviour under varying density conditions.

A clear research gap nonetheless remains in identifying empirical thresholds that directly link passenger perception to measurable crowding indicators at the platform level. Existing studies rarely translate perceived acceptance into quantifiable parameters such as critical density or interpersonal spacing. Moreover, limited research has been conducted in developing countries, where commuter rail systems operate under more intense crowding conditions and passenger adaptation behaviours may differ significantly from theoretical assumptions.

This gap is particularly pressing in the context of Jabodetabek commuter rail stations, where extreme passenger density has become a routine rather than exceptional condition. The mismatch between normative LOS standards and actual passenger tolerance may lead to ineffective planning decisions if left unaddressed. Understanding how passengers perceive and tolerate crowding conditions is therefore essential for improving station design, crowd management strategies, and overall service quality in high-demand urban rail systems.

In response to this issue, the novelty of this study lies in integrating stated preference-based perception analysis with binary logistic regression to determine a critical density threshold and convert it into an acceptance distance. Unlike conventional studies that rely solely on physical density or LOS classification, this approach incorporates user acceptance behaviour as a core measurement, enabling the development of a more human-centred evaluation framework for platform service quality.

The primary purpose of this study is to evaluate passenger acceptance of platform crowding conditions and to identify the critical density level at which passengers transition from acceptance to rejection of crowding situations. In addition, the study aims to compare the empirically derived threshold with Fruin's LOS classification to examine the consistency between normative standards and actual user perception, particularly in the context of commuter rail stations in Indonesia.

This study contributes to transportation planning and railway station management by providing an empirical model linking passenger density with acceptance probability. The specific objective is to estimate a critical density threshold and derive an acceptance distance that can serve as a practical indicator for evaluating platform crowding conditions. These findings are expected

to support the development of more responsive and user-oriented service quality indicators beyond traditional engineering-based measures.

The benefits of this research extend to both theoretical and practical domains. Theoretically, it enriches the literature on transit crowding by integrating behavioural perception with quantitative density modelling. Practically, the findings can assist railway operators and planners in designing more effective crowd control strategies, improving passenger flow management, and enhancing platform safety and comfort. Ultimately, this study supports the development of more adaptive and perception-based standards for evaluating commuter rail station performance.

METHOD

Study Area

This study was conducted at Depok Commuter Station, one of the busiest commuter rail stations in the Jakarta Metropolitan Area (Jabodetabek), Indonesia. The station serves a large number of daily commuters and experiences substantial passenger concentration during peak periods. The platform area was selected as the unit of analysis because it functions as the primary waiting space before boarding and directly reflects passenger interactions with crowding conditions.

Data Collection

A stated preference (SP) survey was employed to collect passenger perceptions regarding platform crowding conditions. The survey targeted individuals who had prior experience using commuter rail services and station platforms. Respondents were presented with a series of hypothetical crowding scenarios represented by different passenger density levels on a platform.

The density scenarios ranged from low-density to highly crowded conditions and were designed to represent realistic platform situations commonly encountered at commuter rail stations. For each scenario, respondents were asked whether the condition was still acceptable or unacceptable from their personal perspective. Responses were recorded as a binary variable, where “accepted” was coded as 1 and “not accepted” was coded as 0.

A total of 297 respondents participated in the survey. Each respondent evaluated ten density scenarios, generating 2,970 observations for statistical analysis.

Research Variables

The study utilized passenger density as the independent variable and passenger acceptance as the dependent variable. Density was expressed in passengers per square meter (passengers/m²), while acceptance represented the respondent’s willingness to tolerate a specific crowding condition.

Table 1. Research Variables

Variable	Type	Unit	Description
Density	Independent	Passengers/m ²	Passenger concentration on the platform
Acceptance	Dependent	Binary (0/1)	Passenger acceptance of crowding conditions

Data Analysis

The relationship between passenger density and acceptance probability was analyzed using binary logistic regression. Logistic regression was selected because the dependent variable consisted of two possible outcomes: accepted and not accepted.

The logistic regression model is expressed as:

$$\text{Logit}(P) = \beta_0 + \beta_1 D$$

where:

P = probability of acceptance;

D = passenger density (passengers/m²);

β_0 = intercept;

β_1 = regression coefficient.

The probability of acceptance was estimated using the logistic function:

$$P = \frac{1}{1 + e^{-(\beta_0 + \beta_1 x)}}$$

The significance of the model was evaluated through likelihood ratio tests and goodness-of-fit indicators. The estimated model was subsequently used to identify the critical density threshold.

Determination of Critical Density and Acceptance Distance

Critical density was defined as the density level at which the probability of acceptance equals the probability of rejection ($P = 0.50$). This threshold represents the point where passengers are equally likely to accept or reject a crowding condition.

The identified critical density was then converted into acceptance distance through the relationship between density, space per person, and interpersonal spacing. The resulting acceptance distance was compared with Fruin's Level of Service (LOS) classification to evaluate the consistency between normative service standards and actual passenger perceptions.

RESULTS AND DISCUSSION

Respondent Characteristics

A total of 297 respondents participated in the survey. All respondents had prior experience using commuter rail services and station platforms. Through the stated preference survey, each respondent evaluated ten platform crowding scenarios, resulting in 2,970 observations used in the statistical analysis. The large number of observations provided a sufficient basis for estimating passenger acceptance behavior under different crowding conditions.

Relationship Between Density and Passenger Acceptance

The relationship between platform density and passenger acceptance was analyzed using binary logistic regression. The estimated model is expressed as:

$$\text{Logit}(P) = 5.205 - 0.777D$$

where P represents the probability of acceptance and D represents passenger density (passengers/m²).

The negative coefficient of density (-0.777) indicates that increasing passenger density significantly reduces the probability of passenger acceptance. The statistical significance of the coefficient ($p < 0.001$) confirms that density is an important determinant of perceived platform acceptability.

The resulting logistic curve demonstrates a gradual decline in acceptance probability as density increases. At lower density levels, passengers generally considered platform conditions acceptable. However, as density increased, the probability of acceptance decreased substantially, indicating a reduction in perceived comfort and available personal space.

These findings are consistent with previous crowding studies, which reported that increasing passenger concentration negatively affects comfort, satisfaction, and overall travel experience. The result also supports the theoretical assumption that reductions in personal space increase the likelihood of discomfort and crowding perception among public transport users.

Critical Density Threshold

One of the primary objectives of this study was to identify the critical density threshold representing the transition point between acceptable and unacceptable crowding conditions.

Based on the estimated logistic model, the critical density was determined by setting the acceptance probability equal to 0,50. The analysis produced a critical density value of:

$$\text{Critical Density} = 6,70 \text{ passengers/m}^2$$

This value represents the point at which passengers are equally likely to accept or reject the crowding condition. Densities below this threshold are generally perceived as acceptable, while densities above the threshold tend to be perceived as unacceptable.

The logistic curve indicates that the transition between acceptance and rejection becomes particularly pronounced within the density range of approximately 6 - 7 passengers/m². Within this interval, relatively small increases in density generate substantial changes in passenger perception, highlighting the sensitivity of user acceptance near the threshold level.

The identification of a critical density threshold provides an empirical indicator that can support operational decision-making and crowd management strategies at commuter rail stations.

Acceptance Distance Analysis

To provide a more intuitive interpretation of the threshold value, the critical density was converted into an acceptance distance representing the minimum interpersonal spacing still considered acceptable by passengers.

The analysis yielded an acceptance distance of:

$$\text{Acceptance Distance} = 0,386 \text{ m}$$

This value indicates that passengers can generally tolerate interpersonal spacing of approximately 38,6 cm under platform waiting conditions. Beyond this threshold, perceived comfort decreases and acceptance probability declines substantially.

Compared with density-based indicators, acceptance distance provides a more practical representation of passenger perception because it directly relates to personal space requirements. Consequently, this measure may be easier for planners and station operators to interpret when evaluating platform crowding conditions.

Comparison with Fruin's Level of Service Classification

The acceptance distance obtained from the empirical analysis was compared with Fruin's Level of Service (LOS) classification. Fruin's framework evaluates service quality primarily based on passenger density and available space per person.

The comparison revealed that the empirically derived threshold corresponds to crowding conditions associated with lower LOS categories. However, the results also indicate that actual passenger acceptance does not necessarily align perfectly with normative LOS boundaries.

This finding suggests that passengers may tolerate crowding levels differently from those implied by conventional design standards. Such differences may be influenced by travel habits, commuter experience, cultural factors, and adaptation to crowded urban transport environments.

Therefore, while LOS classifications remain useful for facility planning and capacity assessment, the incorporation of passenger perception provides additional insight into how crowding conditions are actually experienced by users.

Practical Implications

The findings demonstrate that passenger-based evaluation can complement conventional service quality assessment methods. The identified critical density of 6.70 passengers/m² and acceptance distance of 0.386 m may serve as empirical reference values for monitoring platform crowding conditions.

From an operational perspective, station operators may utilize these thresholds to identify situations where passenger comfort begins to deteriorate significantly. Such information can support crowd management measures, passenger flow regulation, platform design improvements, and service planning strategies aimed at maintaining acceptable comfort levels.

Overall, the study highlights the importance of integrating objective crowding indicators with subjective passenger perceptions in evaluating platform service quality.

CONCLUSION

The study concludes that passenger density has a significant negative effect on passenger acceptance of platform crowding conditions at commuter rail stations. Using a stated preference approach and binary logistic regression analysis, the research successfully identified a critical density threshold of 6.70 passengers/m², which represents the point at which passengers are equally likely to accept or reject crowding conditions. This threshold corresponds to an acceptance distance of approximately 0.386 meters, indicating the minimum interpersonal space still tolerated by users in platform environments. Furthermore, the comparison with Fruin's Level of Service (LOS) classification reveals that normative density-based standards do not fully align with actual passenger perceptions, highlighting the importance of incorporating user-based evaluation in assessing platform service quality.

Future research is recommended to expand the scope of analysis across different stations, cities, and transit systems to improve the generalizability of the findings. Subsequent studies may also integrate additional behavioral and contextual variables such as travel purpose, cultural adaptation, psychological comfort, and real-time crowd dynamics to provide a more

comprehensive understanding of passenger acceptance behavior. Methodologically, future research could combine logistic modeling with advanced approaches such as structural equation modeling or agent-based simulation to capture more complex interactions in crowding perception. In addition, longitudinal studies are suggested to observe how passenger tolerance evolves over time in response to increasing urban density and improvements in transportation infrastructure.

REFERENCES

- Andrikopoulou, E., & Spyropoulou, I. (n.d.). Mind the Gap: Harmonising Pedestrian Infrastructure Evaluation Metrics-The Case of Walkability and Level of Service. *Available at SSRN 5534130*.
- Cats, O., Zhang, C., & Nissan, A. (2016). Survey methodology for measuring passenger perceptions of public transport crowding. *Transportation Research Part A: Policy and Practice*, 95, 6-19.
- de Ona, J., de Ona, R., Eboli, L., & Mazzulla, G. (2015). Perceived service quality in public transport services: A structural equation approach. *Transport Policy*, 29, 219-226.
- Direktorat Jenderal Perkeretaapian. (2023). Statistik Perkeretaapian Indonesia 2023. Jakarta: Ministry of Transportation of the Republic of Indonesia.
- Fedujwar, M., et al. (2024). Crowding valuation in public transport: A review and meta-analysis. *Transportation Research Record*, 2678(4), 112-128.
- Hänseler, F. S., Bierlaire, M., & Scarinci, R. (2016). Assessing the usage and level-of-service of pedestrian facilities in train stations: A Swiss case study. *Transportation Research Part A: Policy and Practice*, 89, 106–123.
- Hensher, D. A., Rose, J. M., & Greene, W. H. (2015). *Applied Choice Analysis: A Primer* (2nd ed.). Cambridge: Cambridge University Press.
- Lombardi, D. B., & Ciceri, M. R. (2021). Dealing with feeling crowded on public transport: The potential role of design. *Environment and Behavior*, 53(4), 339–378.
- Louviere, J. J., Flynn, T. N., & Carson, R. T. (2020). Discrete Choice Experiments Are Not Conjoint Analysis. *Journal of Choice Modelling*, 34, 100-115.
- Nikiforiadis, A., Basbas, S., Mikiki, F., Oikonomou, A., & Polymeroudi, E. (2021). Pedestrians-cyclists shared spaces level of service: comparison of methodologies and critical discussion. *Sustainability*, 13(1), 361.
- Obsie, A., Woldeamanuel, M., & Woldetensae, B. (2020). Service quality of addis ababa light rail transit: Passengers' views and perspectives. *Urban Rail Transit*, 6(4), 231–243.
- Pu, Y. S., Srikukenthiran, S., Morrow, E., Shalaby, A., & Klumpenhouwer, W. (2022). Capacity analysis of a passenger rail hub using integrated railway and pedestrian simulation. *Urban Rail Transit*, 8(1), 1–15.
- Raad, N., & Burke, M. (2017). Pedestrian Levels-of-Service tools: problems of conception, factor identification, measurement and usefulness. *39th Australasian Transport Research Forum (ATRF 2017)*.
- Rasoolimanesh, S. M., Jaafar, M., Marzuki, A., & Abdullah, S. (2019). Examining the effects of

- personal factors and travel characteristics on tourists' perceived crowding. *European Journal of Tourism Research*, 22, 5–19.
- Rodrigue, J. P. (2020). *The Geography of Transport Systems* (5th ed.). New York: Routledge.
- Seriani, S., Aprigliano, V., Minatogawa, V., Peña, A., Lopez, A., & Gonzalez, F. (2025). Passenger Service Time at the Platform–Train Interface: A Review of Variability, Design Factors, and Crowd Management Implications Based on Laboratory Experiments. *Applied Sciences*, 15(15), 8256.
- Shi, Z., Pan, W., He, M., & Liu, Y. (2025). Understanding passenger route choice behavior under the influence of detailed route information based on smart card data. *Transportation*, 52(2), 615–639.
- Tirachini, A., Hensher, D. A., & Rose, J. M. (2017). Crowding in public transport systems: Effects on users, operation and implications for the estimation of demand. *Transportation Research Part A: Policy and Practice*, 53, 36-52.
- Wang, B., & Zacharias, J. (2020). Noise, odor and passenger density in perceived crowding in public transport. *Transportation Research Part A: Policy and Practice*, 135, 215–223.
- Xu, X., Cong, J., & Xia, T. (2024). A study of the impact of the use of real-time crowding information on the perceived service quality of high-speed rail by passengers with unfixed-seat tickets. *Applied Sciences*, 14(2), 535.