Developing and Validating a Methodological Framework for Assessing First and Last Mile Accessibility: A Pilot Study in Kuala Lumpur

Evi Puspitasari[1,3], Choon Wah Yuen[1,2*], and Mohd Rasdan Ibrahim[1,2]

[1] Department of Civil Engineering, Faculty of Engineering, Universiti Malaya, Kuala Lumpur 50603, Malaysia
[2] Center for Transportation Research, Universiti Malaya, Kuala Lumpur 50603, Malaysia
[3] Department of Civil Engineering, Faculty of Engineering, Universitas Tidar 56116, Magelang, Indonesia
*yuencw@um.edu.my

Abstract. First-mile and Last-Mile (FMLM) connectivity is critical to ensuring seamless integration within public transport networks. However, accessibility remains challenging due to mode availability, travel cost, and reliability. This study designs and implements a pilot study to evaluate the impact of reliability variables on FMLM accessibility and mode choice in Kuala Lumpur's rail transit system. The study employs a concept to develop a research instrument by integrating latent constructs and analyzing them in structural equation modelling (SEM). This study also develops the construct by adjusting the attributes in the SP experiment and validating it in multinomial logit (MNL) models. Data were collected through an intercept survey at selected LRT and MRT stations, focusing on socio-demographics, accessibility indicators, and reliability perceptions. Findings indicate that the survey instrument and its variables fulfil the validity and reliability test, although some variables like IF2, AV2, RE5, and PE1 require refinement. The result also shows that availability, Travel Cost, and Travel Time Distance significantly influence Accessibility. The study further highlights discrepancies between stated and actual mode choices, suggesting the need for hybrid models integrating revealed preference (RP) data. Future research should incorporate a longitudinal approach and employ nested logit or latent class models to refine FMLM accessibility models.

Keywords: FMLM, accessibility, pilot study, validity, SEM, Stated Preference

1 Introduction

As highlighted in various studies, first and last-mile (FMLM) connectivity faces significant challenges in public transport systems. The problems primarily occur when people experience difficulties accessing or departing from the main public transport routes, creating barriers to seamless travel [1]. [2] stressed that it is essential to consider infrastructure capabilities, reliability, and accessibility to achieve better mobility and

X. Qu et al. (eds.), *Proceedings of the 14th Asia-Pacific Conference on Transportation and the Environment (APTE 2025)*, Atlantis Highlights in Engineering 41,
https://doi.org/10.2991/978-94-6463-972-8_11

maximize economic and environmental benefits. Similarly, [3] in [4] identified FMLM access as a frequent bottleneck in passengers' journeys and underlined the necessity of optimizing factors such as cost, station assignments, micro-level design, and the integration among transport systems. Furthermore, [5] reported that competition among multiple feeder modes, such as walking and cycling, significantly affects public transport preferences for FMLM connectivity. These findings underscore the importance of addressing FMLM accessibility and mode choice challenges to ensure efficient and sustainable public transport systems.

Research on travel behaviour and transit accessibility in FMLM has been extensive and varied. Studies have explored user satisfaction, mode choice determinants, and latent travel behaviour constructs. [11] employed SEM to examine ride-hailing's role in enhancing FMLM connectivity. They analysed perceived benefits, environmental impact, private car ownership, innovation, and technology adoption. However, the analysis did not incorporate attributes like reliability, availability, and infrastructure quality. The findings underscored ride-hailing's significance, but factors like service frequency, unexpected delays, or wait times have not been fully explored yet. It can be an opportunity to integrate analysis that includes psychological constructs and operational transport metrics to provide an alternative FMLM mode adoption approach. Reliability, encompassing factors such as frequency, schedule adherence, travel time variability, and integration with main transportation modes, is crucial in determining accessibility levels. [14] The study used the Analytical Hierarchy Process (AHP) to rank FMLM factors and integrate them into a nested mode choice model. However, the study did not incorporate reliability as a key determinant in accessibility assessments. Addressing this gap requires a comprehensive approach that adapts analysis, like multimodal models that employ SEM and Multinomial Logit (MNL). The models are used to understand the significant factors of commuter behaviour and accessibility preferences, resulting in more effective FMLM policy interventions and service optimizations.

This research aims to design and implement a pilot study that evaluates the impact of reliability variables on FMLM accessibility and mode choice that supports the rail transit network in Kuala Lumpur. Specifically, the study objectives are to identify a suitable study area and profile the participants by examining their socio-demographic characteristics and travel behaviours relevant to FMLM connectivity. It also seeks to conceptualize and define the dimensions of accessibility and reliability variables, establishing a robust methodological framework. Additionally, the study aims to design a comprehensive survey and research instrument, followed by implementing a pilot survey and data analysis. The pilot analysis includes measuring latent variables and applying statistical methods to ensure the validity and reliability of the constructs. Finally, the study intends to develop a travel mode choice model to evaluate the influence of these variables on mode choice preferences. By achieving these objectives, this research addresses critical gaps in understanding the relationship between accessibility, reliability, and mode choice, providing new insights into enhancing FMLM connectivity for rail transit systems.

2 Methods

2.1 Data Collection and Study Area

Data collection methods in transport studies can vary widely, including documentary searches, observational surveys, household surveys, intercept surveys, group surveys, in-depth interviews, or big data analysis [8]. In alignment with the stated research objectives, which focus on accessibility, reliability, and mode choice in FMLM transport, primary data were collected through an intercept survey conducted at railway station entry and exit points using a structured questionnaire.

This study focused on the Greater Kuala Lumpur region, which includes Wilayah Persekutuan Kuala Lumpur, with a population of 1.982.112, and the Selangor area, with a population of 6.9994.423 (Department of Statistics Malaysia, 2023). The sample chosen will include a broader representation of residents across both urban and suburban areas. Using rail and non-rail users might enhance the generalizability and reduce selection bias. This might support more comprehensive insights into FMLM accessibility and improve the applicability of findings for regional transport planning and policy development.

This study employed a geographically stratified sampling approach. The study area was divided into strata based on station type (first-mile station (around residential area) vs. last-mile station (around city center)). Due to limited resources, not all stations were investigated. The sample size was allocated proportionally to each station's ridership.

An appropriate sample size estimation is required to ensure a representative analysis. This research would use a 95% confidence level. Based on the data, the total population (N) is 8.976.535. Since the population number is vast, the infinite population approach is applied, and the required sample size is 385 respondents. The pilot survey should be five to ten percent of the final survey data. Given that the infinite population sample size is 385 respondents, if it applies to 10% of the total primary data, the pilot survey size is 10% * 385 = 39 respondents. By adopting these structured methods, this study will ensure the minimization of errors and the optimization of data collection.

The survey instrument was developed based on a comprehensive literature review, and the final pilot sample consisted of 66 respondents. The questionnaire was translated into English and Bahasa Malaysia, with back-translation performed to ensure consistency.

2.2 Concept and Dimension for Accessibility Variables

Different perspectives influence how accessibility is measured and analyzed, integrating transport systems, land use, temporal dimensions, and individual factors [9]. Accessibility is evaluated through various dimensions, integrating key practical considerations, conceptual evaluations, and secondary factors [11]. Key practical considerations include proximity, access to opportunities (travel distance, time, and cost), trip characteristics, and qualitative measures such as perceptions and barriers. The conceptual evaluation of accessibility considers infrastructure, network connectivity, quality of transport facilities, destination location and availability, travel mode options, and

experiential aspects such as perceived safety and unmet travel needs. From an accessibility dimension perspective, factors like travel impedance, opportunity type, and person/place perspectives influence how accessibility is assessed. Impedance factors include sidewalk width, street lighting, transit headways, parking availability, reliability, and safety perceptions. Reliability parameters across modes, including headway regularity, waiting time, transfer efficiency, travel time variability, and user perceptions. [11] identified headway regularity and transfer time as crucial factors using stated preference surveys, while [13] emphasized reliability and buffer time, and analyzed using smartcard and AVL data. Additionally, [14] explored crowding and satisfaction impacts on metro and bus systems using latent class-ordered logit models. In this study, reliability is operationalized using the following metrics: how users perceive the alignment of FMLM service schedules with LRT/MRT schedules, whether the nearest public transport stop is at a reasonable distance, whether FMLM service are consistently on time, the extent to which passengers feel the routes are quick and direct, and overall user satisfaction of FMLM transport services. Moreover, secondary dimensions such as travel mode, time of day, and implied origin further refine accessibility analysis. These perspectives demonstrate that accessibility is not just a function of distance or infrastructure but a complex interplay of transport, land use, individual experiences, and broader socio-economic factors.

2.3 Design of Survey and Research Instrument

The survey instrument is developed based on the conceptual framework in Figure 1. The instrument was then developed into construction aspects, which applied a 5-point Likert Scale from strongly disagree to agree strongly [14]. In this section, the exogenous construct is accessibility, while the endogenous factors consist of seven aspects, with each parameter having indicators.

The stated preference instrument presents respondents with hypothetical transport scenarios, enabling an analysis of mode preferences based on accessibility attributes. This experimental design allows for a Multinomial Logit (MNL) model analysis, capturing respondents' trade-offs between cost, time, and reliability to determine their mode preference for first and last-mile connectivity.

2.4 Validity and Reliability

Several steps were undertaken throughout the research to ensure data validity and methodological rigor. Content validity was assessed to determine how well the items in the survey instrument represent the intended concept or research objectives and the established framework [15] in [16]. Accessibility-related questions were adapted from peer-reviewed studies to ensure theoretical grounding. A panel of transportation research experts (this study involved three transportation experts) reviewed the survey instrument [17], providing qualitative input to refine and improve its structure. Construct validity was tested in this pilot study to identify the ambiguous questions, inconsistencies, and potential bias [16]. Additionally, criterion validity was applied to validate state preference (SP) responses, using cross-validation with revealed preference (RP) data

(in this case, we used the actual commuters' mode choice data). Any discrepancies were analyzed to detect potential bias, a common issue in SP studies [18]. Finally, this study also adhered to ethical research guidelines [19] by obtaining informed consent, ensuring voluntary participation, and securing approval from the Universiti Malaya Research Ethics Committee (UMREC).

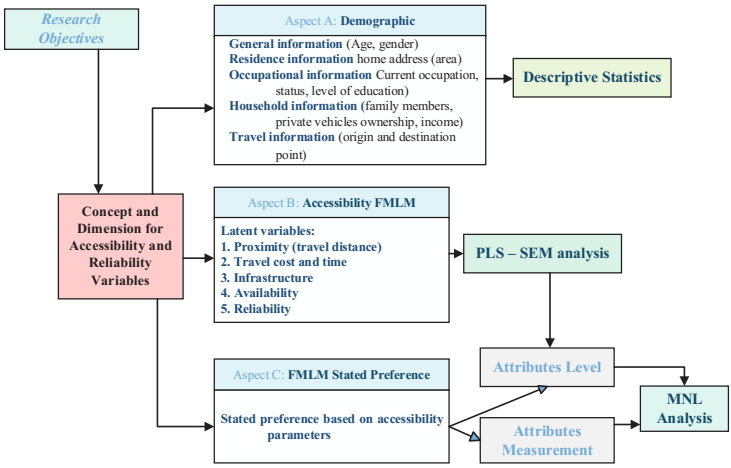

Fig. 1. Conceptual Framework

3 Results

3.1 Content Validity Result

This study established content validity to ensure that the questionnaire accurately reflects key concepts of accessibility and reliability in FMLM transport. Content validity is assessed through stages: the development stage, judgment stage, and revision stage [20]. In this study, the development of accessibility measurement was guided by existing constructs, as described in Section 2.4. Once the questionnaire content was developed, the next step was expert judgment. Three transportation research experts specializing in public transit planning, accessibility assessment, and travel behaviour reviewed the survey instrument. These experts evaluated each item based on relevance, clarity, and comprehensiveness in measuring the intended constructs. Table 1 summarizes the expert feedback and the corresponding revisions implemented in the questionnaire. Based on the expert recommendation in Table 1, twelve questions were modified, four were removed, and two were added to enhance construct coverage.

Table 1. Experts Review of Survey Items and Adjustments

Survey section	Expert Feedback	Modification Implemented
Socio-demographic Section	Some questions lacked clarity: • Household information	• Household and private vehicle ownership questions were clarified.

	• Private vehicle ownership • Monthly income should not be divided into B1, B2, M1, M2, T1, T2 categories Suggested: Add occupational questions	• B1, B2, M1, M2, T1, T2 income categories were removed. • Occupational questions were added.
Accessibility Section	• Revise inconsistencies • Shorten long sentences • Remove redundant questions	• Inconsistent questions and response options were revised. • Overly long questions were simplified. • Redundant questions were eliminated.
Stated Preference Questions	• Revise terms that may be unfamiliar to respondents • Clarify instructions for new scenarios, such as distance criteria	• Unfamiliar terms were revised for better understanding. • Instructions were improved using bold text and a larger font for clarity.

3.2 Measurement of Latent Variables

The structural model comprises seven key constructs: accessibility, reliability, availability, infrastructure, travel cost, travel time and distance, policy and environmental support, and safety. Accessibility is a central construct influenced by other constructs. The measurement model follows a reflective construct approach, where the indicators are manifestations of the underlying latent variables [21]. Reliability, availability, infrastructure, travel cost, travel time, and distance are exogenous variables constructed from multiple indicators. For example, the reliability variable includes psychological and behavioural indicators such as overall satisfaction with FMLM transport services. This reflected in the statement "I am happy with how I travelled during the first and last part of my journey" (RE 5) [22]. User attitudes and trust in the transport system are also illustrated by perceptions like “the transport for the start and end of my journey is always on time” (RE 3) and “the routes are quick and direct” (RE4). Behavioural responses are also shaped by the perceived ease of FMLM modes transfer, such as “I have a good choice of transport for the start and end of my journey” (AV3)[23], “clear signs make finding my way to and from the train stops easy” (Acc2) [22]. These indicators captured attitudes, preferences, and satisfaction levels that shape accessibility outcomes using PLS-SEM's latent variable measurement model.

The construct validity of the latent construct in this study was assessed using outer loading, variance inflation factor (VIF), composite reliability (CR), and average variance extracted (AVE). The results indicate strong validity, with most indicators having high outer loadings (>0.7). However, IF2 (0.448) and AV2 (0.612) had lower loadings, suggesting weaker contributions. Multicollinearity was minimal (VIF < 3), except for RE5 (3.533) and PE1 (4.912), indicating potential redundancy. Internal consistency was confirmed with Cronbach’s Alpha > 0.7 for all constructs, except for Travel Time and Distance (0.698), which remains within an acceptable range. Composite reliability exceeded 0.85, reinforcing measurement consistency, while AVE values > 0.5 confirmed convergent validity, with Travel Cost (0.849), Policy and Environmental Support (0.841), and Travel Time and Distance (0.767) demonstrating exceptionally high values. These results validate that the measurement model has a reflective nature. However, weak loadings (IF2, AV2) and high VIF values (RE5, PE1) require refinement to enhance robustness.

Table 2. Construct Validity Result

Constructs	Indicators	Outer Loading	VIF	Cronbach's Alpha	Composite Reliability	AVE	rho_A
Accessibility	ACC1	0.86	1.716	0.754	0.859	0.671	0.773
	ACC2	0.735	1.346				
	ACC3	0.856	1.674				
Reliability	RE1	0.7	1.683	0.872	0.907	0.662	0.903
	RE2	0.863	2.601				
	RE3	0.773	2.049				
	RE4	0.815	2.156				
	RE5	0.903	3.533				
Availability	AV1	0.786	1.916	0.866	0.9	0.602	0.888
	AV2	**0.612**	1.463				
	AV3	0.875	2.691				
	AV4	0.766	1.78				
	AV5	0.795	2.075				
	AV6	0.799	2.06				
Infrastructures	IF1	0.828	2.268	0.843	0.884	0.53	0.869
	IF2	**0.448**	1.297				
	IF3	0.71	1.816				
	IF4	0.774	2.376				
	IF5	0.884	4.232				
	IF6	**0.605**	1.689				
	IF7	0.756	2.233				
Travel Cost	TC1	0.918	1.956	0.823	0.919	0.849	0.824
	TC2	0.925	1.956				
Travel time and distance	TD1	0.857	1.404	**0.698**	0.868	0.767	0.708
	TD2	0.895	1.404				
Policy and environmental support	PE1	0.941	4.912	0.905	0.941	0.841	0.907
	PE2	0.928	4.538				
	PE3	0.882	2.124				
Safety	SF1	0.871	1.532	0.741	0.885	0.793	0.756
	SF2	0.91	1.532				

The following analysis examines the relationships and significance among the validated variables. These findings will serve as a basis for adjusting the stated preference questionnaire, ensuring that relevant variables are appropriately developed. This analysis employs the PLS-SEM bootstrapping method to assess the strength and significance of relationships between constructs. The path coefficients indicate the strength and direction of relationships between constructs, while t-values and p-values

determine statistical significance [21]. Regarding indicator significance, all outer loadings exceed 0.7, with t-values above 1.96 and p-values = 0, confirming the reliability and validity of the measurement model [21].

Table 3. Direct Relationship

Construct	Path Coefficient	t-value	p-value	Significance
Availability -> Accessibility	0.405	2.432	0.015	Significance
Infrastructure -> Accessibility	0.219	1.299	0.195	Not significance
Policy and Environmental Support -> Accessibility	-0.246	1.925	0.055	Not significance
Reliability -> Accessibility	0.075	0.497	0.619	Not significance
Safety -> Accessibility	0.171	1.623	0.105	Not significance
Travel Cost -> Accessibility	0.285	3.32	0.001	Significance
Travel Time and Distance -> Accessibility	0.207	3.202	0.001	Significance
Availability -> Policy and Environmental Support	0.771	14.155	0.001	Significance
Infrastructure -> Travel Time and Distance	0.241	1.547	0.123	Not significance
Policy and Environmental Support -> Safety	0.706	12.225	0.001	Significance
Reliability -> Availability	0.852	20.778	0.001	Significance
Reliability -> Travel Cost	0.627	7.353	0.001	Significance
Safety -> Infrastructure	0.781	18.903	0.001	Significance
Travel Time and Distance -> Travel Cost	0.016	0.135	0.892	Not significance

3.3 Development of Travel Mode Choice Model

In this study, reliability was initially assumed to influence accessibility. However, the analysis revealed that availability, travel time, travel distance, and travel cost were the most significant determinants of accessibility. These factors are crucial in shaping FMLM accessibility to main transit stations, ultimately influencing users' FMLM mode choice. To further explore FMLM mode choice, this research will employ a two-stage approach by integrating Structural Equation Modelling (SEM) and Multinomial Logit (MNL) modelling. First, SEM evaluates operational and behavioural constructs, including psychological factors such as user satisfaction, attitudes, and reliability. The stated preference survey incorporated various existing transport alternatives, including feeder buses, car-hailing services, e-scooters, private vehicles, and walking. The validated latent variable scores from SEM are then incorporated into the MNL model as explanatory variables.

For the study to be validated, the SP results of mode choice proportion were compared with the respondents' actual choices, as illustrated in Table 3. In Table 3, the SP indicates that walking is the most frequently chosen mode, followed by ride-hailing, bus, private vehicle, and e-scooter. However, discrepancies emerge when compared to the actual mode choices, particularly in ride-hailing and e-scooter. In e-scooter usage, it shows the most striking discrepancy, whereas in actual decisions, it was not selected at all. It might indicate the limited availability of e-scooters in practice or a potential

bias. These differences suggest that in further primary data analysis development, the choice of e-scooter might be considered to remove or enhance different perspectives.

Table 4. Overview of Choices for FMLM Modes

	Bus	Ride-hailing	E-Scooter	Private Vehicle	Walking
Number of responses	528	528	528	528	528
Some responses chose the mode alternatives	102	103	63	96	164
Percentage Chosen Overall	19.32%	19.51%	11.93%	18.18%	31.06%
Actual percentage chosen of the mode choice	26%	9%	0%	23%	42%

4 Discussions

This study developed the research framework in pilot study phases to assess FMLM accessibility and mode choice in Kuala Lumpur's rail transport system. By employing this study, the research focused on the design, implementation, and validation of the survey instrument and the sampling approach. The pilot study was designed to ensure the data collection process's robustness and the analytical framework's validity and reliability. By integrating behavioral and operational dimensions, this study advances methodological strategies to evaluate multimodal transit connectivity in the urban context.

Intercept surveys at LRT/MRT stations captured real-time commuter experiences but posed challenges, such as recruiting peak-hour respondents and ensuring voluntary participation. Although the pilot sample number met the threshold, the proposed full study stage should require expanded time coverage to mitigate time-of-day biases.

The survey instrument was designed to capture latent constructs (accessibility, reliability) and explicit mode choice preferences. A key challenge lay in balancing theoretical background with practical applicability. The pilot study testing further applied construct validity to assess factor loadings. From the analysis, this study found a weak reliability influence on accessibility. Transit literature emphasizes reliability due to its impact on the performance of the public transport system [24] [11]. This study revealed that travel cost and availability dominated the perceptions of accessibility. On the other hand, infrastructure variable IF2 shows a weak loading. It might reflect that Kuala Lumpur might experience lagging micromobility infrastructure integration compared to European cities [25]. While from the SP experiment, less than 20% of SP respondents prioritized ride hailing, which might have higher reliability among other modes, while walking dominated the mode choice. It underscored that cost and convenience might be the primary drivers. This also aligns with a study from [24], who argued that affordability and mode availability often supersede reliability, especially in cities with fragmented FMLM networks.

The study's novel integration of SEM and MNL models addresses a gap in existing FMLM research, which often prioritizes spatial or policy analysis instead of

behavioural heterogeneity. SEM elucidated latent relationships between accessibility and reliability, while MNL quantified mode choice trade-offs under varying serving conditions. Challenges included reconciling reflective indicators (such as infrastructure, availability) with discrete choice attributes (such as travel time). Future studies could enhance this integration by embedding latent variables into choice models as proposed in hybrid choice models, as also noted by [25], who called hybrid models to capture behavioural heterogeneity. This dual approach might contrast with spatial-based frameworks [28] and offers a replicable template for cities with similar ecosystems.

This study faced several challenges during the pilot phase, including respondent selection bias, survey length, and mode choice discrepancies. Some respondents were unfamiliar with e-scooters, as this mode was not as popular as other FMLM modes in Kuala Lumpur. This case might affect the stated preference responses. The discrepancies between SP and actual modes (RP) underscored the need for hybrid models combining SP/RP data to reduce bias. This result aligns with [27] who found that SP experiments might be prone to hypothetical bias and mitigation techniques should be applied based on the circumstances. The pilot study's validation prompting recommendations to refine mode choice sets by excluding underutilized options such as e-scooters or incorporating real-time availability constraints. Furthermore, the survey instrument was also designed comprehensively, which made it long and led to survey fatigue and response accuracy.

Future studies should explore nested logit or latent class models to segment users by unobserved preferences (e.g., cost sensitivity vs. reliability prioritization). Longitudinal data collection could track behavioral adaptations to infrastructure upgrades, while real-time GPS integration may enhance reliability metrics. Finally, expanding the choice set to include emerging modes (e.g., demand-responsive transit) would align methodologies with rapid technological advancements.

5 Conclusion

This study systematically addressed the key stages of survey development, pilot study implementation, and statistical validation. This study employed content, construct, discriminant, and MNL model validity to ensure that it can be implemented in the primary research. The study area was carefully selected, and participants were profiled based on their socio-demographic characteristics and behaviours. The research has conceptualized and defined the accessibility variables, establishing the research framework that aligns with the literature. The survey instrument and research methodology were tested through pilot data collection, and the validity and reliability of the latent construct were comprehensively analysed. Furthermore, developing the travel mode choice model provided critical insights to enhance the attributes and capture better FMLM decision-making.

Despite its contribution, this study has several limitations. First, the pilot study sample size may not fully capture long-term shifts in LRT/MRT passengers' behavior. Future research could employ a longitudinal approach and evolve with infrastructure

developments and policy changes. Second, while the study incorporated multiple FMLM transport modes, it did not explore emerging mobility solutions such as demand-responsive transit or autonomous shuttles. Future studies should investigate how technological advancements and shared mobility innovations impact mode choice and accessibility. Employing Nested Logit or Latent Class Models could also segment commuters based on unobserved behavioral heterogeneity, providing more targeted recommendations for different user groups.

In conclusion, this study advances the understanding of FMLM accessibility parameters and provides empirical evidence that transport availability, cost, and travel time are the key factors shaping commuter decisions. By bridging gaps between behavioral transport research and urban mobility planning, the study offers a replicable framework for policymakers, transit agencies, and urban planners seeking to develop efficient strategies to improve the FMLM transport network and create a seamless rail transit integration network.

Acknowledgments. This research was funded by the Indonesian Education Scholarship, the Center for Higher Education Funding and Assessment, and the Indonesian Endowment Fund for Education. The authors also acknowledge the support provided by Universiti Malaya in facilitating active participation in this conference.

Disclosure of Interests. The authors have no competing interests to declare relevant to this article's content.

References

1. Cornell A (2021) Improving interconnectivity with multimodal transportation. Elsevier
2. Bhatnagar RV, Ram S (2023) Formulating a Railway Station Accessibility (RsAI) Model for Station Hierarchy Classification. Urban Science 7:. https://doi.org/10.3390/urbansci7020048
3. Wang H, Odoni A (2016) Approximating the performance of a “last mile” transportation system. Transportation Science 50:659–675. https://doi.org/10.1287/trsc.2014.0553
4. Liu L, Miller HJ (2022) Measuring the impacts of dockless micro-mobility services on public transit accessibility. Comput Environ Urban Syst 98:101885. https://doi.org/10.1016/j.compenvurbsys.2022.101885
5. Song M, Zhang Y, Li M, Zhang Y (2021) Accessibility of Transit Stops with Multiple Feeder Modes: Walking and Private-Bike Cycling. Sustainability 13:. https://doi.org/10.3390/su13063522
6. Acheampong RA, Siiba A, Okyere DK, Tuffour JP (2020) Mobility-on-demand: An empirical study of internet-based ride-hailing adoption factors, travel characteristics and mode substitution effects. Transp Res Part C Emerg Technol 115:. https://doi.org/10.1016/j.trc.2020.102638

7. Saiyad G, Srivastava M, Rathwa D (2022) Assessment of Transit Accessibility Through Feeder Modes and Its Influence on Feeder Mode Choice Behavior. Arab J Sci Eng 47:4483 – 4497. https://doi.org/10.1007/s13369-021-06082-9
8. Richardson AJ, Ampt ES, Meyburg AH (1995) Survey Methods for Transport Planning
9. Geurs KT, van Wee B (2004) Accessibility evaluation of land-use and transport strategies: Review and research directions. J Transp Geogr 12:127–140. https://doi.org/10.1016/j.jtrangeo.2003.10.005
10. Karner A, Levine K, Alcorn L, et al (2022) Accessibility Measures in Practice: A Guide for Transportation Agencies. National Academies Press
11. Kathuria A, Parida M, Sekhar CR (2020) A Review of Service Reliability Measures for Public Transportation Systems. International Journal of Intelligent Transportation Systems Research 18:243–255. https://doi.org/10.1007/s13177-019-00195-0
12. Dixit M, Brands T, van Oort N, et al (2019) Passenger Travel Time Reliability for Multimodal Public Transport Journeys. Transp Res Rec 2673:149–160. https://doi.org/10.1177/0361198118825459
13. Soza-Parra J, Raveau S, Muñoz JC, Cats O (2019) The underlying effect of public transport reliability on users' satisfaction. Transp Res Part A Policy Pract 126:83–93. https://doi.org/10.1016/j.tra.2019.06.004
14. Chopra G, Madan P, Jaisingh P, Bhaskar P (2019) Effectiveness of e-learning portal from students' perspective: A structural equation model (SEM) approach. Interactive Technology and Smart Education 16:94–116. https://doi.org/10.1108/ITSE-05-2018-0027
15. Straub D, Gefen D (2004) Validation Guidelines for IS Positivist Research. Communications of the Association for Information Systems 13:. https://doi.org/10.17705/1cais.01324
16. Hamed Taherdoost A, Lumpur K (2016) Validity and Reliability of the Research Instrument; How to Test the Validation of a Questionnaire/Survey in a Research
17. Haynes SN, Richard DCS, Kubany ES (1995) Content Validity in Psychological Assessment: A Functional Approach to Concepts and Methods
18. Hensher DA (2010) Hypothetical bias, choice experiments and willingness to pay. Transportation Research Part B: Methodological 44:735–752. https://doi.org/10.1016/j.trb.2009.12.012
19. Saunders MarkNK, Lewis P, Thornhill A (2023) Research Methods for Business Students, Ninth Edition. Pearson Education Limited
20. Almanasreh E, Moles R, Chen TF (2019) Evaluation of methods used for estimating content validity. Research in Social and Administrative Pharmacy 15:214–221
21. Hair JF., Hult GTM., Ringle CM., Sarstedt Marko (2017) A primer on partial least squares structural equation modeling (PLS-SEM). Sage
22. Dianin A, Gidam M, Hauger G, Ravazzoli E (2024) Measuring public transport accessibility to fixed activities and discretionary opportunities: a space–time

approach. European Transport Research Review 16:. https://doi.org/10.1186/s12544-024-00636-2
23. Grahn R, Qian S, Hendrickson C (2023) Optimizing first- and last-mile public transit services leveraging transportation network companies (TNC). Transportation (Amst) 50:2049 – 2076. https://doi.org/10.1007/s11116-022-10301-z
24. Soza-Parra J, Raveau S, Muñoz JC (2022) Public transport reliability across preferences, modes, and space. Transportation (Amst) 49:621–640. https://doi.org/10.1007/s11116-021-10188-2
25. Abramovic B, Tuda K, Sipus D (2022) The Potential of Using Micromobility to Connect to Urban Rail in an Integrated Passenger Transport System. In: Prentkovskis O, Yatskiv I, Skackauskas P, et al (eds) TRANSBALTICA XII: TRANSPORTATION SCIENCE AND TECHNOLOGY. SPRINGER INTERNATIONAL PUBLISHING AG, GEWERBESTRASSE 11, CHAM, CH-6330, SWITZERLAND, pp 705–716
26. Rich J (2024) Let's walk! The fallacy of urban first- and last-mile public transport. Transportation (Amst). https://doi.org/10.1007/s11116-024-10505-5
27. Adnan M, Altaf S, Bellemans T, et al (2019) Last-mile travel and bicycle sharing system in small/medium sized cities: user's preferences investigation using hybrid choice model. J Ambient Intell Humaniz Comput 10:4721–4731. https://doi.org/10.1007/s12652-018-0849-5
28. Bhatt D, Minal (2022) GIS and Gravity Model-Based Accessibility Measure for Delhi Metro. Iranian Journal of Science and Technology - Transactions of Civil Engineering 46:3411–3428. https://doi.org/10.1007/s40996-021-00795-5
29. Fifer S, Rose J, Greaves S (2014) Hypothetical bias in Stated Choice Experiments: Is it a problem? And if so, how do we deal with it? Transp Res Part A Policy Pract 61:164–177. https://doi.org/10.1016/j.tra.2013.12.010