Logistica : Journal of Logistic and Transportation
E-ISSN : 3032-2766
Volume. 4 Issue 2 April 2026
Page No: 136-156

Beyond Spatial Proximity: Integrating GIS and User Perceptions to Assess Public Transport Accessibility in Indonesian Medium-Sized Cities

Ahmad Hariri[1], Genny Luhung Prasojo[2], Ahnis Zulkarnain[3], Ronny Durrotun Nasihien[4]
[1]Politeknik Penerbangan Palembang, Indonesia
[2]Akademi Penerbang Indonesia Banyuwangi, Indonesia
[3]Politeknik Penerbangan Medan, Indonesia
[4]Universitas Narotama, Indonesia
Correspondent: hazul50@gmail.com[1]

Received : February 20, 2026
Accepted : March 26, 2026
Published : April 30, 2026

Citation: Hariri, A., Prasojo, G, L., Zulkarnain, A., & Nasihien, R, D. (2026). Beyond Spatial Proximity: Integrating GIS and User Perceptions to Assess Public Transport Accessibility in Indonesian Medium-Sized Cities. Logistica : Journal of Logistic and Transportation, 4(2), 136-156
https://doi.org/10.61978/logistica.v4i2

ABSTRACT: Public transport accessibility is fundamental to sustainable urban mobility, yet conventional GIS-based spatial indicators often fail to capture commuters' lived experiences. This study integrates GIS-based and perception-based accessibility measures to provide a more comprehensive understanding of conditions in Indonesian medium-sized cities. A qualitative multiple-case study design was conducted across four cities—Malang, Mataram, Pontianak, and Kendari—involving fourteen informants including commuters, operators, planners, elderly passengers, and a person with disability. Data were gathered through semi-structured interviews, field observations, document review, and spatial analysis, then analyzed using open, axial, and selective coding alongside cross-case comparison, integrating spatial and qualitative findings. Results reveal that objective spatial accessibility and perceived accessibility are often inconsistent, producing four typologies combining high/low spatial and perceived accessibility. Key factors shaping perceived accessibility include walkability, sidewalk continuity, pedestrian safety, service reliability, waiting time, route suitability, information availability, intermodal integration, and inclusive infrastructure. Some residents near transit stops reported poor accessibility due to discontinuous pedestrian infrastructure and unreliable services, while others accepted longer walking distances when services were predictable and affordable—showing accessibility depends on the entire travel experience, not just spatial proximity. The study concludes that GIS indicators should be complemented by perception-based measures, offering an integrated framework to identify mismatches between infrastructure and commuter experience and support inclusive, user-centered transport planning in Indonesian medium-sized cities.

Keywords: Public Transport Accessibility, Geographic Information System, Perceived Accessibility, Walkability, Qualitative Multiple-Case Study, Sustainable Urban Mobility, Indonesian Medium-Sized Cities

This is an open access article under the CC-BY 4.0 license

INTRODUCTION

Public transport accessibility is a central element of sustainable urban development because it determines the extent to which residents can reach employment, education, healthcare, commercial activities, and other essential urban opportunities. In rapidly urbanizing contexts, accessibility is particularly important for reducing dependence on private vehicles, improving social inclusion, and supporting more efficient land-use and transport systems. Conventional accessibility assessment has largely relied on objective spatial indicators generated through Geographic Information Systems(Cadiz et al., 2023; Darmawan et al., 2023; Horita et al., 2015). These indicators typically include distance to the nearest stop, service coverage, route density, catchment size, and the spatial distribution of land uses around transit facilities. Methodological studies of transit-oriented development influence areas commonly define station catchments through walking distances and access times, after which GIS is used to measure land-use composition, street-network characteristics, and multimodal connectivity within those areas (Ann et al., 2019; Jeong et al., 2023; Thakur & Walia, 2024). Built-environment audits are also frequently combined with GIS analysis to evaluate pedestrian infrastructure, sidewalk connectivity, and safety conditions surrounding public transport stops, thereby producing indicators that can be linked to station-level accessibility or ridership outcomes (Nasri et al., 2020; Schlossberg et al., 2013; Silva et al., 2019).

In medium-sized and developing-city contexts, GIS-based accessibility analysis often concentrates on delineating station or stop catchments and evaluating the arrangement of density, land-use diversity, destinations, and street networks within those catchments. The 5D and 6D frameworks commonly referring to density, diversity, design, destination accessibility, distance to transit, and, in some applications, demographic characteristics have been widely used to operationalize the relationship between built form, walkability, and transit access (Moini, 2015; Shen et al., 2017; Silva et al., 2019). Street-network distance is generally considered more appropriate than straight-line distance because actual walking routes are shaped by intersections, barriers, disconnected streets, and the availability of formal pedestrian infrastructure (Schlossberg et al., 2013; Nasri et al., 2020). Likewise, transit-oriented development and station-area studies use GIS to quantify land-use mix, urban density, destination accessibility, and multimodal access around transit stops (Clifton, 2019; Fillone & Mateo-Babiano, 2018). Such approaches provide a systematic basis for identifying spatial disparities and potential service gaps, but their analytical value remains limited when they are treated as complete representations of accessibility.

The main research problem arises from the assumption that spatial proximity or network coverage necessarily translates into ease of access. A public transport stop may be located within a conventionally acceptable walking distance, yet the journey to that stop may remain difficult because of discontinuous sidewalks, unsafe crossings, poor lighting, physical obstructions, extreme weather exposure, or inaccessible boarding facilities. Conversely, some users may perceive public transport as accessible even when the nearest stop is relatively distant, particularly when services are frequent, predictable, affordable, and well matched to their travel needs. Perceived accessibility therefore differs conceptually from objective accessibility because it concerns individuals' subjective evaluations of how easily they can reach desired destinations using available transport options. This distinction has been emphasized in studies showing that users' experiences of safety, comfort, route quality, and operational reliability can diverge substantially from GIS-derived measures of travel time or distance (Silva et al., 2019; Shen et al., 2017).

Addressing this problem requires an integrated approach that recognizes accessibility as both spatial and experiential. Objective measures remain necessary for identifying the geographical distribution of transport infrastructure, but subjective evidence is needed to determine whether that infrastructure is practically usable. Perceived accessibility includes assessments of service frequency, timetable reliability, waiting conditions, personal security, pedestrian quality, comfort, and ease of obtaining travel information. It is also influenced by socio-demographic and socio-spatial conditions that shape people's physical ability, resources, and confidence when using transport services (Brodeur-Ouimet & Cloutier, 2024; Chidambara & Gupta, 2018; Tzouras et al., 2023). The pedestrian environment around stops is particularly important because safety, comfort, route continuity, and visual quality affect whether individuals are willing to walk to and from public transport facilities (Chidambara & Gupta, 2018; Tzouras et al., 2023; Schlossberg et al., 2013). These considerations indicate that accessibility evaluation should not be restricted to where services are located, but should also examine how users experience the complete journey.

Existing literature offers several specific solutions to the limitations of conventional accessibility measurement. One approach is to integrate GIS-generated indicators with surveys, interviews, or environmental audits that capture users' evaluations of first-mile and last-mile conditions. Empirical studies have repeatedly documented differences between objective and perceived accessibility, showing that proximity alone cannot explain whether commuters choose to walk to transit or consider a station easy to access (Silva et al., 2019). Research around metro and rail stations has found that perceived walkability, placemaking quality, and pedestrian comfort affect walking shares beyond the influence of measurable distance to transit (Chidambara & Gupta, 2018; Tzouras et al., 2023; Fillone & Mateo-Babiano, 2018). Studies of transit-oriented development similarly demonstrate that the quality of the surrounding environment shapes accessibility perceptions in ways that are not captured by basic proximity measures (Jeong et al., 2023; Shen et al., 2017; Silva et al., 2019). These findings justify the use of qualitative evidence to interpret GIS outputs and identify the mechanisms producing mismatches between spatial and perceived accessibility.

A second solution emphasizes walkability and first-mile/last-mile connectivity as core components of public transport accessibility. Higher levels of density, diversity, street-network connectivity, destination accessibility, and proximity to transit are generally associated with greater walking access and stronger transit use (Jeong et al., 2023; Moini, 2015; Silva et al., 2019). However, first-mile and last-mile accessibility depends not only on urban form, but also on continuous sidewalks, safe crossings, feeder services, micro-mobility options, and the overall usability of access routes. Improvements to these conditions can expand functional catchment areas and increase the attractiveness of public transport (Venter, 2020). Evidence from different urban settings indicates that pedestrian improvements, feeder systems, and micro-mobility connections can strengthen perceived accessibility and transit use, sometimes more effectively than improvements made only within the transport system itself (Harumain et al., 2021; Jamaleddin et al., 2022; Salter & Alexander, 2022).

A third solution involves broadening accessibility assessment to include service quality. Commuters evaluate the entire journey rather than only the geographic position of stops. Safety, reliability, frequency, travel time, comfort, fare levels, information accessibility, and convenience are repeatedly identified as major components of transit attractiveness and perceived accessibility (Alkhereibi et al., 2023). The quality of walking routes, including sidewalk conditions, crossings, lighting, and network continuity, strongly influences willingness to use public transport (Chidambara & Gupta, 2018). In addition, placemaking elements such as public spaces, greenery, and attractive station surroundings may improve route enjoyment and perceived security (Park et al., 2019). These findings indicate that accessibility should be treated as the product of interactions among spatial structure, service operation, the pedestrian environment, and user characteristics.

Despite the growing literature on integrated accessibility, important gaps remain. Most GIS-based and transit-oriented development studies focus on metropolitan rail systems, high-capacity corridors, or large urban regions. Medium-sized cities in developing countries receive comparatively limited attention, even though they often face weak first-mile and last-mile infrastructure, fragmented pedestrian networks, unsafe access routes, inconsistent feeder services, and limited coordination between land-use and transport planning (Hamidi & Moazzeni, 2019; Sugihara et al., 2018). Strategies developed for larger or more affluent cities may not be directly transferable because transit catchments, informal transport systems, travel cultures, and institutional capacities vary substantially. In many developing cities, walking and informal feeder modes remain central to transit access, while infrastructure quality and maintenance are uneven (Ann et al., 2019; Li et al., 2024; Hamidi & Moazzeni, 2019). There is therefore a need for context-sensitive research that connects spatial indicators with users' lived experiences across different medium-sized urban systems.

This study aims to integrate GIS-based and perception-based measures of public transport accessibility in Malang, Mataram, Pontianak, and Kendari, four Indonesian medium-sized cities with contrasting transport conditions. It examines how spatial accessibility corresponds with commuters' evaluations of walkability, safety, reliability, waiting time, information availability, route suitability, intermodal integration, and inclusive access. The study is guided by the proposition that objective spatial accessibility does not automatically produce positive perceived accessibility and that service quality and first-mile/last-mile conditions explain a substantial part of the divergence between the two. Its novelty lies in developing an empirical accessibility typology that distinguishes high and low combinations of spatial and perceived accessibility and in applying this framework comparatively across multiple Indonesian cities. By incorporating the experiences of commuters, older users, a person with disability, transport operators, and local government planners, the research provides a multidimensional basis for accessibility planning that extends beyond conventional GIS proximity analysis.

METHOD

Research Design

This study employed a qualitative multiple-case study design to examine the relationship between GIS-based and perception-based measures of public transport accessibility in four Indonesian medium-sized cities. A multiple-case design was selected because public transport accessibility is shaped by local spatial structures, service characteristics, pedestrian environments, institutional arrangements, and user experiences. Comparing several cities therefore allows accessibility to be examined not as a uniform technical condition, but as a context-dependent phenomenon that may vary across urban settings.

Case-based research has been widely used to investigate first-mile and last-mile accessibility, walkability, and placemaking around public transport facilities. Studies of metro station environments in Delhi, for example, have combined user accounts and environmental audits to identify how pedestrian infrastructure and station-area characteristics influence walking behavior and last-mile connectivity (Chidambara & Gupta, 2018; Tzouras et al., 2023). Research on station influence zones and transit-oriented development also demonstrates the value of selecting contrasting station-area or urban cases to understand how accessibility conditions differ according to spatial configuration, land use, and transport system characteristics (Ann et al., 2019; Alkhereibi et al., 2022). Similarly, studies using environmental justice and placemaking perspectives have shown that comparative case analysis can reveal variations in walkability, safety, and accessibility across neighborhoods and demographic groups (Brodeur-Ouimet & Cloutier, 2024).

The multiple-case strategy was therefore appropriate for this study because it enabled both within-case interpretation and cross-case comparison. Each city was treated as a distinct case, while individual informants provided experiential evidence regarding access conditions, service performance, and barriers to public transport use. The design also allowed the study to compare objective spatial conditions with subjective evaluations and to identify recurring or contrasting accessibility patterns across the four cases.

Study Areas and Case Selection

The study was conducted in April 2025 in Malang, Mataram, Pontianak, and Kendari. These cities were purposively selected as examples of Indonesian medium-sized cities with different public transport structures, levels of service coverage, pedestrian conditions, and operational characteristics.

Malang represents a relatively dense urban area with established public transport corridors and comparatively strong spatial coverage in central districts. Mataram has a more compact urban form but displays variation in service consistency and inclusive infrastructure. Pontianak is characterized by mixed accessibility conditions and uneven operational performance across different corridors. Kendari represents a more spatially dispersed context in which public transport infrastructure is relatively limited and user adaptation plays an important role in accessibility experiences.

The selection of contrasting cases follows methodological recommendations from studies of transit-oriented development and station influence areas, which emphasize the importance of examining diverse urban environments rather than assuming that a single spatial or operational model applies uniformly across locations (Ann et al., 2019; Alkhereibi et al., 2022). Case-oriented research on first-mile and last-mile connectivity in Delhi and Manila similarly demonstrates that comparison across different urban and station-area contexts can produce transferable insights regarding pedestrian access, environmental quality, and modal choices (Chidambara & Gupta, 2018; Chidambara, 2019; Fillone & Mateo-Babiano, 2018).

Informant Selection

Fourteen informants were selected purposively to represent diverse user and stakeholder perspectives. The sample included daily commuters, university students, private-sector employees, civil servants, traders, teachers, a nurse, a courier, an entrepreneur, a public transport driver, an elderly passenger, a person with disability, a regional transport planner, and a public transport operator.

The use of purposive sampling was intended to capture differences in travel needs, mobility constraints, frequency of public transport use, occupational schedules, and physical abilities. This diversity was particularly important because perceived accessibility is not experienced uniformly. Age, gender, occupation, disability, travel frequency, and familiarity with the transport system can affect how individuals evaluate walking distance, safety, waiting time, vehicle access, route suitability, and service reliability.

Two institutional informants were included to complement the commuter perspectives. The transport planner provided insight into spatial planning, service coverage, and GIS-based evaluation, while the operator contributed information concerning route management, operational constraints, vehicle deployment, and service reliability. Their accounts were used to interpret the institutional and operational context surrounding commuter experiences rather than to classify them within the commuter accessibility typology.

Informants were identified using initials to protect their identities. The use of initials also allowed interview narratives to remain traceable across coding, analysis, and reporting without disclosing personal names.

Data Collection

Data were collected through in-depth interviews, field observations, documentation, and GIS-based spatial analysis. These methods were combined to generate a multidimensional understanding of accessibility.

In-Depth Interviews

Semi-structured interviews were used to explore informants' experiences of accessing and using public transport. Questions addressed distance to stops, walking conditions, sidewalk continuity, safety, crossing facilities, waiting time, service frequency, route suitability, fare affordability, information availability, intermodal transfers, comfort, and accessibility for older persons and users with disabilities.

Interview-based research is widely used to examine transport accessibility because it reveals subjective experiences that cannot be derived from spatial indicators alone. Thematic analysis of interview transcripts has been employed in studies of walkability, placemaking, and last-mile travel behavior to identify patterns in users' perceptions of access, safety, comfort, and environmental quality (Chidambara & Gupta, 2018).

The interviews were conducted in locations familiar and convenient to the informants. The length and structure of each interview allowed respondents to explain both routine travel experiences and specific barriers that influenced their decisions to use or avoid public transport.

Field Observation and Environmental Audit

Field observations were conducted to examine pedestrian routes, stop locations, sidewalk conditions, crossing facilities, lighting, physical barriers, stop amenities, and boarding environments. These observations provided contextual evidence for evaluating whether informants' descriptions corresponded with actual conditions.

Environmental audits are commonly used alongside interviews in transport accessibility studies. Audit-based approaches allow researchers to document sidewalk connectivity, pedestrian safety, street furniture, crossing quality, and other physical characteristics that shape first-mile and last-mile accessibility (Chidambara & Gupta, 2018; Chidambara, 2019). Combining interviews with observations also strengthens analytical triangulation by comparing perceived conditions with visible infrastructure.

Documentation

Relevant transport planning documents, service information, route materials, and institutional records were reviewed where available. Document analysis provided additional information regarding formal accessibility objectives, transport service provision, and planning priorities.

Content analysis of transport policies, transit-oriented development guidelines, and planning documents has been used in previous research to assess whether institutional accessibility objectives correspond with local conditions and user experiences (Ann et al., 2019; Alkhereibi et al., 2022). In this study, documentary evidence was used to contextualize interview findings and institutional perspectives.

GIS-Based Spatial Analysis

GIS analysis was used to provide objective spatial information on public transport accessibility. The analysis focused on variables such as distance to stops, stop distribution, service coverage, catchment areas, route accessibility, and network connectivity.

GIS and qualitative evidence perform complementary functions. GIS provides measurable information concerning distance, land-use patterns, walking catchments, and network structure, while interviews reveal safety perceptions, route difficulties, service uncertainty, and individual preferences that are not directly visible in spatial data (Schlossberg et al., 2013; Jeong et al., 2023). The study therefore treated GIS results as one dimension of accessibility rather than as a definitive representation of users' experiences.

Data Analysis

The qualitative data were analyzed through open coding, axial coding, selective coding, and cross-case comparison.

Open Coding

Interview transcripts were first examined line by line to identify descriptive concepts related to accessibility. Initial codes included distance to stops, sidewalk condition, safety, waiting time, frequency, route suitability, affordability, information access, transfer difficulty, comfort, and boarding barriers.

Axial Coding

The initial codes were grouped into broader analytical categories. For example, sidewalk condition, crossing availability, and walking comfort were categorized under walkability and pedestrian accessibility. Waiting time, schedule consistency, and service frequency were grouped under service reliability. Boarding difficulty and limited ramp access were categorized under inclusive accessibility.

Theory-informed coding was also used to connect the empirical categories with established concepts such as walkability, placemaking, safety, and first-mile and last-mile connectivity. Similar approaches have been used to develop explanatory frameworks from transport interviews and environmental observations (Chidambara & Gupta, 2018).

Selective Coding

Selective coding identified the central themes explaining perceived accessibility. These themes included walkability, reliability, safety, information availability, route coverage, affordability, intermodal integration, and universal accessibility.

Cross-Case Analysis

Findings were compared across cities and informants to identify similarities, differences, and recurring patterns. Cross-case analysis examined why similar spatial conditions generated different accessibility perceptions and why some users reported positive accessibility despite relatively unfavorable spatial conditions.

Integration of GIS and Interview Data

GIS indicators were compared with interview-derived perceptions for each commuter informant. This integration produced four categories: high spatial–high perceived accessibility, high spatial–low perceived accessibility, low spatial–high perceived accessibility, and low spatial–low perceived accessibility.

The integration process involved linking spatial indicators with qualitative themes such as safety, route quality, reliability, and placemaking. This approach is consistent with research that connects GIS-derived measures to user perceptions to explain why spatial proximity may not translate into positive accessibility or increased walking (Jeong et al., 2023; Silva et al., 2019; Chidambara, 2019). Convergent comparison between interview evidence, field observations, and GIS outputs strengthened the interpretation of accessibility mismatches.

Trustworthiness and Triangulation

The credibility of the findings was strengthened through methodological triangulation. Interview accounts were compared with field observations, documentary evidence, GIS results, and stakeholder perspectives. This process reduced reliance on any single source of evidence.

The use of commuters, transport operators, and government planners also supported perspective triangulation. Differences between these accounts were retained analytically because they revealed contrasting understandings of accessibility. GIS outputs provided objective spatial context, while qualitative evidence explained the practical and experiential significance of those spatial patterns.

Ethical Considerations

Participation was voluntary, and informants were informed about the academic purpose of the study. Personal identities were protected through the use of initials. Interview materials were interpreted and reported in a manner intended to preserve confidentiality, avoid unnecessary disclosure, and accurately represent participants' experiences.

RESULT AND DISCUSSION

Overview of the Empirical Findings

The analysis revealed that public transport accessibility in the four Indonesian medium-sized cities could not be explained adequately through spatial proximity alone. Although GIS-based indicators provided an objective representation of stop location, service coverage, and route distribution, commuters' experiences were also shaped by the quality of pedestrian access, service reliability, personal safety, information availability, route suitability, and inclusive infrastructure. The integration of spatial and perception-based evidence therefore produced a more differentiated understanding of accessibility conditions across Malang, Mataram, Pontianak, and Kendari.

Four principal accessibility categories emerged from the comparison between spatial accessibility and perceived accessibility. These categories were high spatial–high perceived accessibility, high spatial–low perceived accessibility, low spatial–high perceived accessibility, and low spatial–low perceived accessibility. The presence of all four categories indicates that objective and subjective accessibility were neither identical nor consistently aligned. Some informants who lived close to public transport stops still considered access difficult, while others who lived farther away perceived public transport as relatively accessible because the service was predictable, affordable, or compatible with their daily routines.

The findings also showed that perceived accessibility was influenced by a combination of built-environment and operational characteristics. Walkability, sidewalk continuity, crossing safety, lighting, waiting time, service frequency, schedule reliability, digital information, and boarding conditions repeatedly appeared in the interview data. These factors interacted rather than operating independently. A short distance to a stop, for example, did not guarantee positive accessibility when the walking route was unsafe or physically obstructed. Similarly, a longer walking distance was not always viewed negatively when service frequency and route suitability were considered dependable.

Spatial Accessibility Patterns Across the Four Cities

The GIS-oriented and interview-based evidence indicated that spatial accessibility varied substantially across the four study locations. Malang generally displayed relatively strong spatial accessibility in central urban corridors. Several informants reported short walking distances to stops, particularly in areas connected to educational, commercial, and employment centers. DS, VN, and AR lived within relatively convenient walking distance of public transport facilities. However, their experiences differed because the physical quality of access routes and service performance were not uniform. This finding is consistent with the broader literature showing that compact catchments and short network distances do not necessarily translate into equivalent accessibility experiences.

Mataram also showed comparatively favorable spatial accessibility in several central locations. ML and BR both lived near public transport stops, while RP described relatively good stop coverage in central areas. Nevertheless, RP emphasized that some residential and peripheral districts remained insufficiently served. This suggests that spatial accessibility was uneven within the city rather than uniformly high. Such internal variation corresponds with research showing that medium-sized cities may contain compact and accessible central corridors alongside fragmented peripheral networks.

Pontianak exhibited more mixed spatial conditions. FN and HT described relatively long distances to public transport access points, while IM reported that a stop was located close to his residence. This contrast demonstrates how accessibility can vary significantly between neighborhoods within the same city. In addition, the operator perspective provided by EJ indicated that stops were more strategically located in central areas, while route development remained constrained by road-network conditions.

Kendari showed the most visible contrast between limited spatial access and user adaptation. SK and YD reported relatively long walking distances, while AL lived within a more accessible catchment. Despite the lower spatial accessibility experienced by some users, YD continued to regard public transport as reasonably accessible because the route matched his work needs and morning service was sufficiently frequent. This illustrates how spatial disadvantage may be partially offset by service predictability and user familiarity.

These results support the literature suggesting that medium-sized cities exhibit highly context-dependent accessibility patterns. Urban form, land-use distribution, transit network design, and pedestrian connectivity jointly influence spatial accessibility (Jeong et al., 2023; Moini, 2015; Shen et al., 2017; Silva et al., 2019). Research also emphasizes that GIS-defined catchments should be calibrated to local travel behavior because acceptable walking distances and influence-zone sizes vary between cities (Ann et al., 2019; Hamidi & Moazzeni, 2019). The present findings similarly show that standard distance thresholds would not capture the full diversity of accessibility across the four cities.

Limitations of GIS-Based Accessibility Measures

The comparison between GIS-based conditions and interview evidence revealed several limitations in relying exclusively on spatial accessibility indicators. First, GIS measures could identify distance and coverage but could not adequately represent whether walking routes were safe, comfortable, continuous, or usable by people with mobility limitations. AR, for instance, lived approximately 500 meters from a stop, which could be interpreted as favorable spatial accessibility. However, discontinuous sidewalks, roadside walking, inadequate lighting, and uncertain waiting times led him to perceive access as difficult.

Second, standard catchment measures did not capture boarding barriers or universal-design deficiencies. BR lived relatively close to a stop in Mataram, yet the route was difficult to navigate by wheelchair because ramps were limited and pedestrian infrastructure was not continuous. The stop therefore appeared accessible spatially but remained inaccessible in practical terms. This mismatch demonstrates that physical proximity cannot be treated as a sufficient indicator for users with different mobility capabilities.

Third, GIS measures did not reflect the reliability or predictability of transport services. A stop could be nearby and a route could be present, but irregular vehicle arrivals and long waiting times reduced the practical value of that spatial access. IM's case in Pontianak illustrated this problem: the stop was close, but the service was considered insufficiently reliable and insufficiently connected to his business destinations.

Fourth, locally specific factors such as informal feeder modes, habitual walking behavior, and adaptation were not fully visible in spatial datasets. FN lived approximately one kilometer from a stop but still perceived access positively because she was accustomed to walking and considered the service affordable and predictable. Similarly, YD accepted an 800-meter walking distance because the route served his needs and the morning service was relatively dependable.

These empirical findings align with identified limitations in GIS-based accessibility research. Spatial models may abstract from perceived safety, route comfort, environmental quality, and individual capability. Standard walking buffers may not represent actual behavior, local norms, or barriers along the route. Data quality and scale may also affect accessibility estimates, particularly in developing or medium-sized cities where information on pedestrian networks and informal feeder services can be incomplete (Silva et al., 2019; Chidambara & Gupta, 2018).

Perceived Accessibility and the Pedestrian Environment

The pedestrian environment emerged as one of the most influential determinants of perceived accessibility. Informants repeatedly referred to sidewalk continuity, surface quality, safe crossings, roadside traffic, lighting, obstructions, and exposure to weather. These findings indicate that commuters assessed accessibility through the complete access journey rather than through distance alone.

In Malang, DS and VN reported relatively positive experiences because their walking routes included usable sidewalks, recognizable stops, and comparatively adequate lighting or crossing facilities. By contrast, AR described interruptions in the pedestrian network, occupation of sidewalks by parked vehicles or traders, and the need to walk on the road shoulder. Although his stop was not distant, these conditions reduced comfort and safety and increased the perceived effort required to reach public transport.

In Mataram, ML considered the route to the stop relatively convenient, although some sidewalk sections were used for parking. RP, however, emphasized that damaged and disconnected sidewalks remained common in several areas. BR's experience demonstrated the importance of universal design because a route that was acceptable for an able-bodied commuter remained difficult for a wheelchair user.

In Kendari, SK identified the absence of sidewalks as a major barrier, especially because age increased her sensitivity to walking distance, boarding difficulty, and road safety. YD was more tolerant of similar infrastructural limitations because traffic was less intense and he was accustomed to walking. This contrast suggests that the same environmental condition may be evaluated differently depending on physical ability, age, travel experience, and purpose.

The results support previous research showing that pedestrian environment quality strongly shapes perceived accessibility and willingness to walk to public transport. Sidewalk continuity, lighting, safety, wayfinding, route aesthetics, and placemaking can affect accessibility perceptions as strongly as, or more strongly than, in-vehicle service characteristics (Chidambara & Gupta, 2018; Brodeur-Ouimet & Cloutier, 2024). Station-area studies also show that GIS-derived land-use and network measures are most informative when combined with audits of crossings, sidewalks, and safety features (Schlossberg et al., 2013; Nasri et al., 2020; Silva et al., 2019).

Service Reliability and Waiting Time

Service reliability was one of the most consistent themes across the interviews. Informants frequently associated accessibility with confidence that a vehicle would arrive within a reasonable and predictable period. Long or uncertain waiting times reduced perceived accessibility even when stops were close and fares were affordable.

AR identified irregular vehicle arrival as one of the main reasons for avoiding public transport during time-sensitive journeys. HT reported waiting periods that frequently exceeded 25 minutes and described schedule uncertainty as the largest barrier to regular use. IM similarly emphasized that limited frequency and uncertain waiting time made private vehicles more attractive despite the nearby stop.

Positive perceptions were associated with greater reliability. ML considered morning services sufficiently frequent for commuting to work, while VN reported relatively dependable arrivals. FN accepted a longer walking distance because waiting times of approximately 10–15 minutes remained predictable. YD also evaluated accessibility positively because morning frequency was compatible with his work schedule.

The findings confirm that accessibility is not only a function of reaching the transport system but also of being able to complete a journey with confidence. Reliability and predictability reduce the perceived burden of waiting and increase users' trust in the transport service. These findings are consistent with research identifying reliability, safety, comfort, and access-route quality as core components of transit attractiveness and perceived accessibility (Alkhereibi et al., 2022; Tzouras et al., 2023; Chidambara & Gupta, 2018). The results further suggest that service reliability interacts with walkability. A long or uncomfortable walk may be accepted when service is predictable, whereas a short walk may still be viewed negatively when vehicle arrivals are uncertain.

Information, Route Suitability, and Intermodal Integration

Information availability also influenced perceived accessibility. Several users relied more heavily on personal experience, transport communities, or informal communication than on official systems. AR indicated that a real-time tracking application would significantly improve confidence in the service. FN relied mainly on accumulated experience, while SK often asked drivers or other passengers for information. By contrast, DS, AL, and VN used map applications or social media to support route planning.

Route suitability was similarly important. Users evaluated whether public transport served their actual destinations and whether transfers were required. ML and VN reported direct or suitable routes, which strengthened positive perceptions. HT and SK faced less favorable conditions because some destinations required transfers or remained outside effective service coverage. AR also noted that journeys toward peripheral areas often required multiple vehicles.

Intermodal integration remained limited in several cases. Transfer points were not always physically connected, and passengers sometimes had to walk additional distances between services. These transfer conditions increased travel time and reduced convenience. The findings indicate that perceived accessibility depends not only on the nearest stop but also on the continuity of the entire trip chain.

Accessibility Typology

The integrated analysis classified twelve commuter informants into four accessibility types. DS, ML, VN, and AL represented high spatial–high perceived accessibility. Their relatively favorable spatial position was reinforced by acceptable pedestrian conditions, suitable routes, adequate information, and comparatively reliable services.

AR, RP, IM, and BR represented high spatial–low perceived accessibility. Their cases demonstrate that proximity did not guarantee ease of use. Unreliable schedules, poor sidewalks, limited route suitability, and inaccessible infrastructure weakened perceived accessibility.

FN and YD represented low spatial–high perceived accessibility. Both accepted relatively long walking distances because they were accustomed to the routes and considered the service sufficiently useful, affordable, or reliable.

HT and SK represented low spatial–low perceived accessibility. Long access distances were combined with weak pedestrian infrastructure, long waiting times, limited routes, and mobility-related difficulties.

This typology provides empirical evidence that objective and subjective accessibility should be analyzed together. It also demonstrates that policy responses should differ by category. High spatial–low perceived cases require improvements in service quality and pedestrian conditions, whereas low spatial–high perceived cases may benefit from targeted stop expansion without disrupting valued service characteristics. Low spatial–low perceived cases require more comprehensive intervention involving network expansion, first-mile and last-mile improvements, and inclusive design.

Summary of Results

Overall, the findings show that public transport accessibility in Indonesian medium-sized cities is produced through the interaction of spatial proximity, pedestrian conditions, operational reliability, information systems, route suitability, and user capability. GIS-based indicators remain valuable for identifying spatial coverage and service gaps, but they do not independently explain whether commuters experience public transport as accessible. The four-category typology demonstrates that similar spatial conditions can produce different perceptions and that similar perceptions can arise under different spatial conditions. Integrating GIS-based and perception-based measures therefore provides a more accurate and policy-relevant representation of accessibility.

The findings demonstrate that public transport accessibility in Indonesian medium-sized cities cannot be adequately represented through GIS-based spatial indicators alone. Although proximity to stops, network coverage, catchment size, and route distribution provide essential information about the spatial availability of services, they do not fully explain whether commuters experience public transport as easy, safe, reliable, and practically usable. The four accessibility categories identified in this study high spatial–high perceived, high spatial–low perceived, low spatial–high perceived, and low spatial–low perceived show that objective and subjective accessibility may align, but may also diverge substantially. This finding supports the principle that accessibility should be treated as a multidimensional construct combining spatial opportunity with the lived experience of reaching, waiting for, boarding, and using public transport. GIS provides the objective spatial context, while perception-based evidence reveals barriers and enabling conditions related to safety, comfort, information, placemaking, and service reliability that conventional spatial analysis may fail to detect (Silva et al., 2019; Chidambara & Gupta, 2018).

The high spatial–low perceived cases provide the clearest evidence of the limitations of proximity-based planning. AR, IM, RP, and BR were located relatively close to public transport facilities, yet they reported difficulties associated with discontinuous sidewalks, uncertain vehicle arrivals, limited route suitability, poor intermodal integration, or inaccessible boarding conditions. Their experiences indicate that a stop situated within an acceptable walking distance does not automatically produce meaningful accessibility. For BR, the presence of a nearby stop was undermined by the absence of continuous ramps and wheelchair-accessible infrastructure. For AR and IM, service uncertainty reduced the practical value of nearby facilities. These findings reinforce arguments that GIS-based catchments should be modified by qualitative information on route quality, safety, environmental barriers, and user capability. Standard walking buffers may overestimate accessibility when they fail to account for difficult crossings, obstructed sidewalks, poor lighting, steep surfaces, inaccessible vehicles, or unreliable services (Ann et al., 2019; Chidambara & Gupta, 2018).

The low spatial–high perceived cases also challenge conventional assumptions. FN and YD lived farther from public transport stops, yet perceived access positively because the service was affordable, useful, sufficiently reliable, and compatible with their daily routines. Familiarity with the route, willingness to walk, and predictable morning services reduced the subjective burden associated with longer distances. This suggests that accessibility cannot be interpreted solely as the minimization of spatial separation. It also depends on whether users can anticipate and manage the journey. These findings are consistent with the literature showing that service reliability, route suitability, and first-mile and last-mile conditions interact to shape perceived accessibility and transit attractiveness (Alkhereibi et al., 2022; Tzouras et al., 2023; Chidambara & Gupta, 2018). A longer walk may remain acceptable where the service is dependable, whereas a short walk may still be perceived negatively when the waiting time is uncertain or the route is unsafe.

Walkability emerged as a central explanatory factor across all four cities. The interview evidence consistently referred to sidewalk continuity, road safety, crossings, lighting, obstructions, weather exposure, and boarding ease. These results confirm that public transport accessibility begins before passengers enter a vehicle. The pedestrian environment therefore functions as a critical link between spatial coverage and actual use. Studies of Delhi, Montréal, Manila, and other urban contexts similarly show that sidewalk quality, safety, lighting, wayfinding, placemaking, and route aesthetics strongly influence the willingness to walk to transit and may be as important as in-vehicle service characteristics (Fillone & Mateo-Babiano, 2018; Chidambara, 2019). For the cities examined here, improving pedestrian access may produce greater accessibility benefits than simply adding new stops in areas where the existing first-mile and last-mile environment remains poor.

Service reliability was equally influential. Users evaluated accessibility partly through their confidence that a vehicle would arrive within a reasonable and predictable period. Long waiting times, irregular service, and limited operating hours reduced perceived accessibility even when fares were affordable and stops were nearby. Conversely, predictable service strengthened positive evaluations among users who faced longer walking distances. Reliability thus operates as an experiential modifier of spatial accessibility. This relationship is especially important in medium-sized cities, where transport services may be less frequent, digital information may be incomplete, and users often rely on personal experience or informal sources. Improving reliability, schedule adherence, and real-time information would therefore enhance accessibility without necessarily requiring immediate network expansion.

An integrated planning framework should respond to these findings through an iterative combination of GIS and perception-based evidence. GIS can first be used to identify areas with low service coverage, long network distances, weak connectivity, or limited access to major destinations. Interviews, environmental audits, and user surveys can then explain why some apparently well-served locations remain difficult to access and why some poorly served areas generate relatively positive user experiences. These qualitative insights should be fed back into spatial analysis by adjusting walking thresholds, weighting unsafe or inaccessible routes differently, and incorporating service reliability, route quality, and user capability into accessibility assessments (Silva et al., 2019; Chidambara & Gupta, 2018). Such an approach would move accessibility analysis from static mapping toward a locally calibrated decision-support system.

The policy implications differ across the accessibility typologies. High spatial–low perceived areas require improvements in pedestrian quality, service frequency, information systems, safety, and universal design rather than additional stops alone. Low spatial–high perceived areas may benefit from selective route or stop expansion while preserving service reliability and affordability. Low spatial–low perceived areas require comprehensive intervention involving network expansion, feeder services, safer pedestrian corridors, and improved operational performance. High spatial–high perceived areas should be maintained and monitored to prevent deterioration. Across all categories, continuous sidewalks, safer crossings, lighting, wayfinding, seating, shelter, accessible boarding, and seamless transfer information are likely to improve perceived accessibility (Chidambara & Gupta, 2018; Tzouras et al., 2023). Feeder services, micro-mobility, safe cycling links, and coordinated transfers can also expand effective catchments, particularly in cities with dispersed development or weak first-mile and last-mile connectivity (Venter, 2020; Li et al., 2024; Harumain et al., 2021).

The inclusion of subjective accessibility also strengthens sustainable and equitable mobility planning. Spatial proximity may conceal unequal experiences among older adults, women, low-income users, and persons with disabilities. The experience of BR illustrates how conventional indicators can classify a location as accessible while overlooking substantial physical barriers. Similarly, SK's experience shows that age affects the practical meaning of distance, waiting time, and boarding conditions. An environmental justice perspective is therefore necessary to identify which groups experience disproportionate constraints and to target interventions accordingly (Brodeur-Ouimet & Cloutier, 2024). Integrating perception-based measures improves the behavioral relevance of accessibility analysis because it reveals why spatial availability does not always translate into public transport use.

Future research should develop standardized but adaptable protocols for linking GIS measures with interview data, environmental audits, and perception surveys. Walkability indices and catchment thresholds should be calibrated to local urban form, travel culture, climate, pedestrian conditions, and informal transport practices rather than imported directly from metropolitan or Western contexts (Jeong et al., 2023; Ann et al., 2019). Further studies should also examine variation by gender, income, age, disability, and neighborhood type. Dynamic data from applications, sensors, crowdsourcing, and real-time vehicle systems may support more responsive accessibility evaluation (Beck & Oktay, 2023; Cartenì & Henke, 2022). In addition, future frameworks should include walking, cycling, shared mobility, and micro-mobility to represent the complete multimodal journey (Choosakun & Yeom, 2021).

Overall, the study shows that effective accessibility planning requires the integration of spatial coverage, pedestrian conditions, service quality, and user experience. The main contribution is not the rejection of GIS, but its repositioning within a broader analytical framework. GIS identifies where opportunities and deficiencies are located, while perception-based evidence explains how those conditions are experienced and why they influence travel behavior. Bringing both dimensions together enables transport agencies to design interventions that improve not only measurable coverage but also the actual usability, inclusiveness, and attractiveness of public transport.

CONCLUSION

This study examined public transport accessibility in four Indonesian medium-sized cities by integrating Geographic Information System (GIS)-based accessibility measures with commuters' perceived accessibility. Using a qualitative multiple-case study approach, the research demonstrated that accessibility is a multidimensional concept that cannot be adequately explained through objective spatial indicators alone. Although GIS analysis provides essential information regarding the spatial distribution of public transport infrastructure, service coverage, and network connectivity, commuters' experiences are equally influenced by walkability, service reliability, pedestrian safety, information availability, route suitability, intermodal integration, and inclusive infrastructure.

The findings identified four distinct accessibility typologies: High Spatial Accessibility–High Perceived Accessibility, High Spatial Accessibility–Low Perceived Accessibility, Low Spatial Accessibility–High Perceived Accessibility, and Low Spatial Accessibility–Low Perceived Accessibility. These typologies demonstrate that spatial proximity does not necessarily translate into positive accessibility experiences. Several commuters located near public transport stops still perceived accessibility as poor because of discontinuous sidewalks, unsafe pedestrian environments, unreliable services, or inadequate facilities for older adults and persons with disabilities. Conversely, some commuters accepted relatively long walking distances because public transport services were predictable, affordable, and compatible with their daily travel needs. These findings indicate that accessibility results from the interaction between physical infrastructure, operational performance, and users' lived experiences.

The discussion further showed that pedestrian infrastructure and first-mile/last-mile conditions play a central role in shaping perceived accessibility. Continuous sidewalks, safe crossings, adequate lighting, reliable services, and accessible boarding facilities consistently emerged as important determinants of commuters' willingness to use public transport. Service reliability was found to complement spatial accessibility by reducing uncertainty and increasing confidence in daily travel. Consequently, accessibility should be evaluated not only by measuring the location of transport facilities but also by considering how users experience the complete travel chain from origin to destination.

The principal contribution of this research is the development of an integrated accessibility framework that combines GIS-derived indicators with perception-based evidence obtained through qualitative inquiry. Rather than treating objective and subjective accessibility as separate concepts, the proposed framework demonstrates how both dimensions complement one another in explaining public transport accessibility. The resulting accessibility typology provides a practical analytical tool that enables planners to distinguish between infrastructure deficiencies, operational shortcomings, and experiential barriers. This integrated approach extends existing accessibility assessment by incorporating commuter experiences into spatial analysis, thereby offering a more comprehensive understanding of accessibility conditions in medium-sized cities.

The study also contributes to transport planning practice by highlighting the importance of user-centered accessibility evaluation. Policy interventions should move beyond expanding route coverage or increasing the number of public transport stops. Equal attention should be given to improving pedestrian infrastructure, strengthening first-mile and last-mile connectivity, enhancing service reliability, providing accurate real-time travel information, improving intermodal integration, and ensuring universal accessibility for older adults and persons with disabilities. Combining GIS analysis with user perceptions enables transport authorities to prioritize investments that improve both objectively measured accessibility and the quality of commuters' daily travel experiences.

Although the study provides valuable insights, several limitations should be acknowledged. The research was conducted in four Indonesian medium-sized cities using a qualitative design and a purposive sample of informants. Consequently, the findings emphasize analytical depth rather than statistical generalization. Future research may expand the geographical scope by including additional cities with different transport systems and urban forms. Mixed-method approaches combining qualitative evidence with larger-scale quantitative surveys could further validate the proposed accessibility typology. Future studies should also investigate accessibility differences across socio-demographic groups, integrate dynamic mobility data from digital platforms and real-time passenger information systems, and examine the influence of emerging mobility services such as shared mobility and micromobility on first-mile and last-mile accessibility.

In conclusion, this study demonstrates that effective public transport accessibility planning requires an integrated perspective that combines objective spatial analysis with commuters' lived experiences. GIS-based indicators remain indispensable for identifying spatial opportunities and infrastructure gaps; however, they should be complemented by perception-based evidence to capture how accessibility is experienced in everyday travel. By integrating these two dimensions, transport planning can become more responsive, inclusive, and aligned with the principles of sustainable urban mobility, ultimately supporting more equitable and user-centered public transport systems in Indonesian medium-sized cities.

REFERENCE

Alkhereibi, A. H., Wakjira, T. G., Küçükvar, M., & Onat, N. C. (2023). Predictive Machine Learning Algorithms for Metro Ridership Based on Urban Land Use Policies in Support of Transit-Oriented Development. *Sustainability*, *15*(2), 1718. https://doi.org/10.3390/su15021718

Ann, S., Jiang, M., & Yamamoto, T. (2019). Re-Examination of the Standards for Transit Oriented Development Influence Zones in India. *Journal of Transport and Land Use*, *12*(1). https://doi.org/10.5198/jtlu.2019.1534

Beck, L. C., & Oktay, S. Ö. (2023). Designing a Cycling Dashboard as a Way of Communicating Local Sustainability. *Sustainability*, *15*(17), 12829. https://doi.org/10.3390/su151712829

Brodeur-Ouimet, P., & Cloutier, M. (2024). Walkable and Safe Route to Transit for Pedestrians in Greater Montréal: An Environmental Justice Approach. *Transportation Research Record Journal of the Transportation Research Board*, *2678*(9), 562–573. https://doi.org/10.1177/03611981241230309

Cadiz, N. R. R., Mariano, K. L. S., Dumalag, J. B. L. C., Retamar, A. E., & Aceron, J. C. F. (2023). *Information, Education, and Communication Campaign in the Philippines: Capacitating Academic Institutions and Government Agencies using Geographic Information System, Radar Remote*

Sensing, and Artificial Intelligence. https://www.scopus.com/inward/record.uri?eid=2-s2.0-105003874751&partnerID=40&md5=f2fc4df1e093e75454c803c7f2ce8ad7

Cartenì, A., & Henke, I. (2022). Transportation Planning, Mobility Habits and Sustainable Development in the Era of COVID-19 Pandemic. *Sustainability*, *14*(5), 2968. https://doi.org/10.3390/su14052968

Chidambara, & Gupta, S. (2018). Effect of Walkability on Users Choice of "Walking" the Last Mile to Transit Stations: A Case of Delhi Metro. *Urban Studies and Public Administration*, *1*(1), 1. https://doi.org/10.22158/uspa.v1n1p1

Choosakun, A., & Yeom, C. (2021). Developing Evaluation Framework for Intelligent Transport System on Public Transportation in Bangkok Metropolitan Regions Using Fuzzy AHP. *Infrastructures*, *6*(12), 182. https://doi.org/10.3390/infrastructures6120182

Clifton, K. J. (2019). *Transferability &Amp; Forecasting of the Pedestrian Index of the Environment (PIE) for Modeling Applications*. https://doi.org/10.15760/trec.218

Darmawan, C. N., I'zzuddiin, M., & Alina, A. N. (2023). Analysis of Public Green Open Space (RTH) Distribution Using Geographic Information System (GIS) Methods in the Districts of Sumenep City. *Journal of Geospatial, Remote Sensing, and Survey*, *1*(1), 7–16.

Fillone, A. M., & Mateo-Babiano, I. (2018). Do I Walk or Ride the Rickshaw? Examining the Factors Affecting First- And Last-Mile Trip Options in the Historic District of Manila (Philippines). *Journal of Transport and Land Use*, *11*(1). https://doi.org/10.5198/jtlu.2018.1077

Hamidi, S., & Moazzeni, S. (2019). Examining the Relationship Between Urban Design Qualities and Walking Behavior: Empirical Evidence From Dallas, TX. *Sustainability*, *11*(10), 2720. https://doi.org/10.3390/su11102720

Harumain, Y. A. S., Azmi, N. F., & Yusoff, S. (2021). Assessing Elements of Walkability in Women's Mobility. *Journal of the Society of Automotive Engineers Malaysia*, *1*(3), 208–215. https://doi.org/10.56381/jsaem.v1i3.61

Horita, F. E. A., Albuquerque, J. P. D., Degrossi, L. C., Mendiondo, E. M., & Ueyama, J. (2015). Development of a spatial decision support system for flood risk management in Brazil that combines volunteered geographic information with wireless sensor networks. *Computers and Geosciences*, *80*, 84–94. https://doi.org/10.1016/j.cageo.2015.04.001

Jamaleddin, M., Ibrahim, H., Ferwati, M. S., Khamidi, M. F., & Indraganti, M. (2022). Pre-Transit Oriented Development Assessment Guidelines for Assessing Metro Station Dependent Component Area. *Designs*, *6*(3), 56. https://doi.org/10.3390/designs6030056

Jeong, I., Choi, M., Kwak, J., Ku, D., & Lee, S. (2023). A Comprehensive Walkability Evaluation System for Promoting Environmental Benefits. *Scientific Reports*, *13*(1). https://doi.org/10.1038/s41598-023-43261-0

Moini, N. (2015). *Development of an Analytical Framework to Rank Pedestrian and Cyclist Projects*. https://doi.org/10.5038/cutr-nctr-rr-2015-03

Nasri, A., Younes, H., & Zhang, L. (2020). Analysis of the Effect of Multi-Level Urban Form on Bikeshare Demand: Evidence From Seven Large Metropolitan Areas in the United States. *Journal of Transport and Land Use*, *13*(1). https://doi.org/10.5198/jtlu.2020.1615

Salter, B., & Alexander, S. (2022). Getting There: The Effect of First and Last Mile Infrastructure and Services on Rail Ridership. *Transportation Research Record Journal of the Transportation Research Board*, *2676*(10), 402–412. https://doi.org/10.1177/03611981221089543

Schlossberg, M., Meyer, C., Dill, J., & Ma, L. (2013). *Measuring the Performance of Transit Relative to Livability*. https://doi.org/10.15760/trec.135

Shen, Z., Li, J., Zhou, S., Li, M., Chen, Y., Jiang, Y., & Xue, X. (2017). *Weakly Supervised Dense Video Captioning*. 5159–5167. https://doi.org/10.1109/cvpr.2017.548

Silva, D. C. d., King, D. A., & Lemar, S. V. (2019). Accessibility in Practice: 20-Minute City as a Sustainability Planning Goal. *Sustainability*, *12*(1), 129. https://doi.org/10.3390/su12010129

Sugihara, R., Ikaruga, S., Tsuboi, S., Kobayashi, T., Song, J., & Zhao, S. (2018). Proposal of a Support System for Formulating Compact City Planning Based on the City Planning of Portland. *Journal of Architecture and Planning (Transactions of Aij)*, *83*(749), 1251–1261. https://doi.org/10.3130/aija.83.1251

Thakur, D., & Walia, A. (2024). Strategies and Implications That Can Be Used to Improve Walkability Through Urban Design. *Interantional Journal of Scientific Research in Engineering and Management*, *08*(03), 1–5. https://doi.org/10.55041/ijsrem29328

Tzouras, P. G., Mitropoulos, L., Koliou, K., Stavropoulou, E., Karolemeas, C., Antoniou, E., Karaloulis, A., Mitropoulos, K., Vlahogianni, E. I., & Κεπαπτσόγλου, K. (2023). Describing Micro-Mobility First/Last-Mile Routing Behavior in Urban Road Networks Through a Novel Modeling Approach. *Sustainability*, *15*(4), 3095. https://doi.org/10.3390/su15043095

Venter, C. (2020). Measuring the Quality of the First/Last Mile Connection to Public Transport. *Research in Transportation Economics*, *83*, 100949. https://doi.org/10.1016/j.retrec.2020.100949