Infrastructure Reports

WISDOM ACADEMIC ISSN: 3080-7271 | E-ISSN: 3080-728X Volume 1 , Issue 3

Article

Urban Villages Left Behind? A Spatial Equity Analysis of Public Transit in Shenzhen

Yilin Wang*

College of Arts, Anhui University, Hefei 230601, China.

***Corresponding author:** Yilin Wang, 189023229@qq.com.

CITATION

Wang YL. Urban Villages Left Behind? A Spatial Equity Analysis of Public Transit in Shenzhen. Infrastructure Reports. 2025; 1(3): 201.

https://doi.org/10.63808/ir.v1i3.201

ARTICLE INFO

Received: 2 September 2025

Accepted: 5 September 2025

Available online: 5 November 2025

Abstract: Fair access to public transportation is a key foundation for building inclusive urban mobility, yet significant gaps remain between different types of communities. In the context of China's rapid urbanization, few studies have directly compared transportation accessibility between urban villages and formal residential areas. Taking Shenzhen as a case study, this research systematically examines the differences in transport accessibility across these communities. By integrating spatial data on metro stations, bus stops, and community boundaries, and applying geographic and statistical analysis, we assess multiple accessibility indicators. The findings show that formal residential areas enjoy higher transport facility density and more balanced distribution, while urban villages often face fragmented networks or insufficient coverage. These results highlight persistent inequalities in urban transport provision and point to the urgent need for targeted planning to improve accessibility in underserved areas of rapidly growing cities.

Keywords: public transit equity; urban villages; spatial analysis; transit accessibility

1. Introduction

Within this broader analytical framework, particularly in the Global North, transport planning paradigms appear to tend to suggest a substantial transformation—moving from what appears to be a narrow emphasis on operational efficiency toward a broader concern with social equity, spatial justice, and inclusive accessibility. Policy frameworks, such as the U.S. Department of Transportation's Equity Action Plan, the UK's Inclusive Transport Strategy, and the European Commission's Urban Mobility Framework, seem to generally indicate this paradigm shift. Given the complexity of these theoretical relationships, these institutional efforts appear to provide evidence that may support what appears to be a growing body of empirical research employing high-resolution spatial data, accessibility models, and neighborhood-level indicators to evaluate disparities in transit service provision across different socio-economic and spatial contexts. What appears particularly significant about these findings is their capacity to illuminate these complex dynamics (Lucas et al., 2016).

In light of these methodological considerations, urban transport systems in the Global South—particularly within rapidly urbanizing cities—tend to point toward what appears to be distinct and frequently more severe challenges. What the evidence appears to reveal is that accelerated urban expansion typically outpaces infrastructure provision, potentially leading to ostensibly pronounced inequalities in the spatial distribution of transit services. What appears to emerge as significant in this analytical context is the dual structure of many metropolitan areas, where formally planned residential developments coexist alongside informally developed settlements, such as urban villages, thereby compounding this issue. Considering the nuanced nature of these findings, these informal enclaves seem to lend support to what may represent characteristics such as predominantly high residential density, substantial migrant populations, and a seeming exclusion from formal planning and investment frameworks (Wu et al., 2013). What appears to emerge from this evidence is that they frequently remain on the margins of transit provision, tending to raise fundamental questions about the spatial equity of transportation infrastructure and, what seems especially noteworthy in this analytical context, the broader implications for social inclusion and urban justice, what appears to warrant further interpretive consideration.

What also appears significant in this context is that although there has been a growing body of literature examining transport equity within the Chinese context and other parts of the Global South—addressing topics such as accessibility, transit-oriented development (TOD), and socio-spatial inequality (Pan et al., 2009)—from this particular interpretive perspective, the majority of this work tends to point toward what appears to be a reliance on coarse spatial units, such as districts or entire urban regions. What seems to emerge from these findings is that these aggregated approaches seemingly obscure micro-scale variations that are critical to understanding how different settlement types experience transit access in everyday life. What tends to emerge as theoretically important here is the need to capture these nuances, as this appears to complicate traditional interpretations. Within these evolving conceptual parameters, what the investigation appears to indicate, in particular, is that rarely have studies systematically compared formal and informal residential areas at a neighborhood scale, nor have they predominantly examined the distributional characteristics of different transit modes, such as metro and bus systems, using disaggregated spatial data. What seems to distinguish this pattern from conventional understanding is the need for a more granular approach, which appears to warrant further interpretive consideration.

This study addresses these gaps by focusing on three questions: (1) How do metro and bus station densities and clustering patterns differ between urban villages and formal residential areas? (2) Within each settlement type, are transit facilities more evenly distributed, as measured by spatial inequality indicators such as the Gini coefficient? (3) What do the spatial relationships between transit infrastructure and different residential forms reveal about inclusion or marginalization?

This research brings to light variations often hidden in city-level studies. The joint analysis of metro and bus systems also enables a comparison of two transport modes with distinct planning logics and spatial footprints (Pan et al., 2009). Overall, the study advances the literature on transport equity by combining spatial statistical tools with fine-grained residential categories. It offers a methodological framework that can be applied elsewhere and provides practical insights for planners and policymakers working to build more inclusive and accessible mobility systems in rapidly urbanizing cities.

2. Literature Review

The spatial fairness of public transit has become a pressing issue in rapidly urbanizing cities, particularly in countries such as China. As an important aspect of urban equity, spatial equity concerns whether transport infrastructure is distributed fairly across different residential areas (Martens, 2016). A growing body of work has examined how urban form and planning practices influence access to metro and bus networks. A consistent finding is the marked contrast between formal residential communities and informal settlements such as urban villages (Delbosc & Currie, 2011). Urban villages—largely inhabited by migrants and low-income groups—tend to have poorer transit access, despite their greater dependence on public transport (Zhang & Kukadia, 2005). By contrast, formal neighborhoods are often equipped with integrated metro-bus systems, while urban villages are sidelined due to ambiguous legal standing and historical development paths. The following review highlights three dimensions of this issue, with a particular focus on metro and bus accessibility in Shenzhen.

2.1. Public Transport Accessibility and Spatial Equity

Spatial equity in transit refers to a fair and balanced distribution of infrastructure and services relative to population needs, socio-economic factors, and urban structure (Martens et al., 2012). It is now widely recognized as part of transport justice in both academic and policy discussions. In practice, it is assessed using measures such as distance to stations, service frequency, and network connectivity. GIS-based tools are commonly applied, including buffer analysis (Jiao & Dillivan, 2013), kernel density estimation, and network-based travel-time measures (El-Geneidy et al., 2016). Inequalities are further analyzed through Gini coefficients, Lorenz curves, and spatial autocorrelation (e.g., Moran's I, Getis-Ord Gi*) (Delbosc & Currie, 2011). These approaches expose local disparities and systemic bias in provision.

Yet much of the literature focuses on large-scale comparisons between districts or zones, overlooking the neighborhood-level gaps tied to different housing forms. This is a major limitation in Chinese cities, where formal housing and informal urban villages coexist within the same urban fabric but diverge sharply in planning, service access, and social integration.

2.2. Built Environment, Housing Types, and Transit Disparities

The built environment—land use, infrastructure, and design—strongly shapes mobility and perceptions of accessibility (Handy et al., 2002). In China's megacities, formal residential areas are usually built under state planning frameworks and often follow TOD principles, with dense metro-bus networks and pedestrian-friendly layouts. By contrast, urban villages, though centrally located and job-rich, are excluded from formal planning, resulting in weak infrastructure, irregular street patterns, and poor connectivity (Wu et al., 2013).

This marginalization is visible on the ground. Some studies suggest villages benefit from central locations, but others note that poor sidewalks, physical barriers, and safety concerns reduce effective access (Gao et al., 2021). Transit service here is typically uneven, with metro stations spaced farther apart and fewer high-frequency bus routes. For migrants and low-income workers without cars, this lack of provision heightens exclusion.

Although research on transit justice in Global South cities is growing, relatively little links residential morphology directly to service disparities. Fewer still consider intra-urban micro-geographies, such as gated estates versus informal enclaves. This limit understanding of how planning regimes and land tenure interact with infrastructure provision to generate unequal outcomes.

2.3. Location Attributes and Residential Proximity in Transit Accessibility

Proximity to CBDs or major transfer nodes is central to accessibility. Stations in dense employment zones often have multimodal links, high service frequency, and integrated cycling facilities (Ahmed et al., 2008). Formal communities are usually sited close to such nodes, benefiting from short access distances and better amenities. Many urban villages, however, are surrounded by fragmented infrastructure and unsafe walking environments, which diminish actual access (Wu et al., 2013).

Station-level features, such as ridership and transfer capacity, also matter. High-demand or transfer hubs attract more investment (Ahmed et al., 2008). But in urban villages, these advantages are often underused due to poor local integration. The same station can serve formal and informal neighborhoods very differently, making it essential to consider location and residential context together.

2.4. Urban Villages and the Politics of Informality in Transport Provision

Urban villages have become focal points in debates on informality, displacement, and transit exclusion. Emerging outside formal planning, they provide vital low-cost housing and labor support (Liu et al., 2010). Yet they are often overlooked in infrastructure investment, while formal or redeveloped areas receive priority because they align with land value capture, commercial interests, or TOD agendas. Villages thus remain underserved, with fragmented station layouts and weak multimodal integration (Deng & Nelson, 2013). Some villages are adjacent to hubs, while others are isolated, meaning accessibility differs not only between formal and informal areas but also within the urban village category itself. Binary models often miss this nuance, underscoring the need for fine-grained, spatially disaggregated studies.

What this tends to indicate, in summary, is that the literature on public transport accessibility and spatial equity seems to generally indicate what appears to be the centrality of the built environment in influencing what appears to be mobility outcomes. While GIS-based accessibility tools and equity metrics have advanced substantially, current research frequently appears to fall short of adequately capturing the intra-urban disparities that arise from differing residential morphologies, from this particular interpretive perspective (Jing et al., 2018). What tends to emerge as theoretically important is that urban villages, as hybrid spaces of informality and centrality, appear to represent what seems to be critically underexamined areas in terms of their transit provision and infrastructural exclusion. By integrating spatial statistical analysis with typological distinctions in housing form, what this study appears to indicate is a clear intention to address what seems to be these persistent gaps.

3. Method

3.1. Study context and data

3.1.1 Study context

Shenzhen, located on the southern coast of China and bordering Hong Kong, is one of the country's most dynamic and rapidly urbanizing Special Economic Zones. By 2020, the city's permanent population had surpassed 13 million, within an administrative area of 1,997 square kilometers (Yang et al., 2017). Governed through a multilayered administrative system of 10 districts, 74 sub-districts, and numerous neighborhood committees, Shenzhen exemplifies contemporary models of metropolitan governance in China. According to the Shenzhen Master Plan (2010–2020), the city has adopted a polycentric development pattern, with core centers in Futian, Luohu, and Nanshan, and secondary sub-centers in Longhua, Longgang, Guangming, Pingshan, and Yantian (**Figure 1**).

Despite its rise as a global innovation hub and a flagship of China's urban modernization, Shenzhen tends to grapple with what appear to be major spatial challenges, particularly concerning housing equity and infrastructural inclusion. A substantial proportion of its residents—especially low-income migrant workers—appear to reside in "urban villages," what might be characterized as informal high-density settlements that have historically fallen outside formal urban planning (**Figure 2**). While these enclaves appear to be often centrally located and seem to hold substantial socio-economic importance, they tend to be characterized by what appears to be poor living conditions, inadequate infrastructure, and a systematic exclusion from equitable access to public services such as transportation; what appears particularly significant about these findings is the entrenched disadvantage faced by these communities.

To address these disparities, the Shenzhen Municipal Government introduced the Comprehensive Urban Renewal and Improvement Plan (2021–2025), which aims to upgrade more than 1,000 urban villages through differentiated, people-centered strategies. This initiative marks a strategic shift from large-scale demolition toward more fine-grained renewal approaches, including micro-regeneration and on-site upgrading, with a strong focus on improving infrastructure, mobility, public safety, and community facilities (Xu & Yeh, 2005). Crucially, enhancing transport connectivity—particularly integrating urban villages into the metro and bus networks—has been designated as a central policy priority. However, the scale and pace of implementation vary significantly across districts, leaving many urban villages still marginalized during the current stage of renewal.

Infrastructure Reports
WISDOM ACADEMIC ISSN: 3080-7271 | E-ISSN: 3080-728X Volume 1 , Issue 3

Public transportation forms the backbone of Shenzhen's urban mobility system. By the end of 2020, the city had 11 operational metro lines stretching over 400 kilometers, covering major residential and employment areas. Complementing this is an extensive bus network of more than 9,000 routes, which supports a wide range of intra-city travel demands. Yet the distribution of transport infrastructure remains spatially uneven. Planned residential communities are typically well connected to multimodal transit hubs, while urban villages often suffer from fragmented connections, irregular street patterns, and long distances to metro stations or high-frequency bus routes.

An even more pressing challenge is the spatial mismatch between housing and employment. Core job centers—such as the Futian Central Business District (CBD), the Qianhai–Nanshan High-Tech Zone, and the Bao'an Central District—are concentrated in areas where land prices are high and affordable housing is scarce. As a result, large numbers of low- and middle-income workers are compelled to commute long distances from urban villages and surrounding settlements. These dynamic places significant strain on the public transport system, especially during peak hours.

Figure 1

Study area

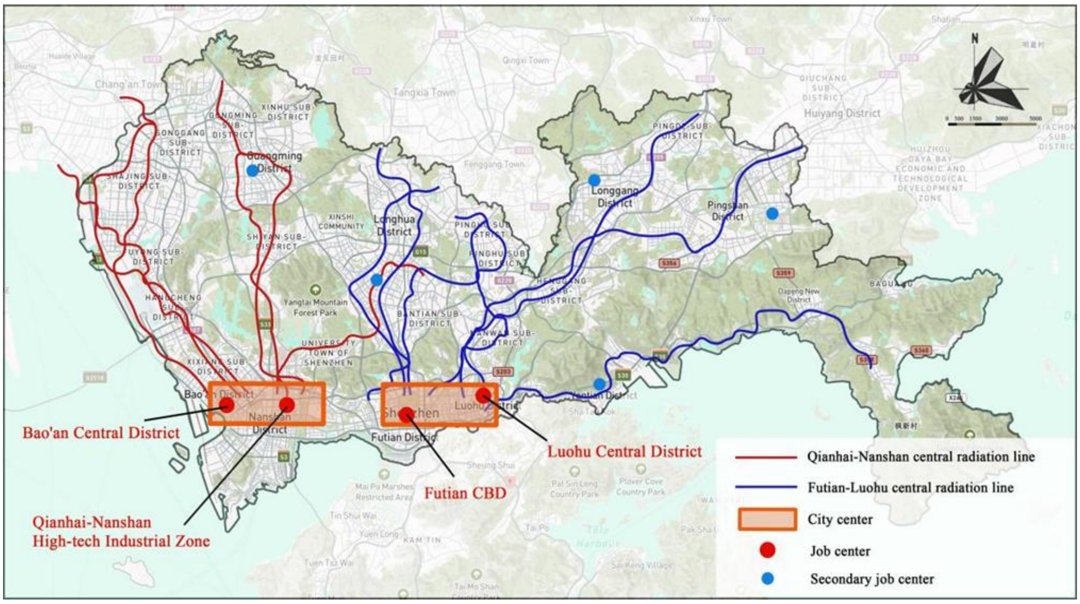
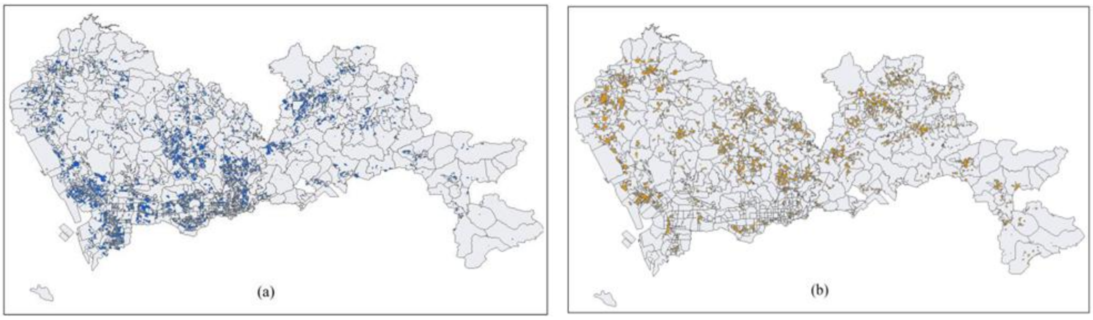


Figure 2

(a) formal residential areas (b) informal residential areas



To mitigate these challenges, Shenzhen appears to have adopted a multimodal integration strategy encompassing bike-sharing programs, improved pedestrian infrastructure, and transit-oriented development (TOD) corridors. However, what the evidence tends to suggest is that the benefits of these policies appear not to have been equitably distributed. Urban villages seem to continue to face both physical and institutional barriers to full integration into the formal transport network, what appears to raise critical concerns around spatial justice, mobility equity, and infrastructural exclusion; what seems especially noteworthy in this analytical context is the persistent challenge of integrating informal settlements into formal urban systems. Within this broader analytical framework, assessing the spatial distribution of public transit services across formal and informal residential typologies appears not to be merely a technical undertaking, but what seems to be a vital issue of urban rights and policy accountability; what tends to emerge as theoretically important here is the re-framing of urban transit not merely as a technical utility but as a fundamental right. What this study appears to do, therefore, is respond to these concerns by conducting a neighborhood-scale evaluation of transit equity in Shenzhen, with a particular focus on how urban villages are situated within the city’s evolving mobility landscape.

3.1.2 Data

What appears to be central to this study is the integration of multiple spatial datasets to analyze the distributional accessibility of public transit in Shenzhen, with a particular focus on the comparison between urban villages and formal residential communities. Given the multifaceted nature of this evidence, what the spatial data for administrative boundaries—including districts, sub-districts, and neighborhood-level divisions—appears to reveal is that they were obtained from OpenStreetMap (2023), a widely recognized open-source platform for geospatial information. What these data seem to have served as is the base layer for defining the urban extent and ostensibly facilitating spatial joins with other vector datasets. What the data for bus stops and metro stations seems to suggest is that they were sourced from the Shenzhen Open Data Platform. What the dataset appears to include are precise point locations and operational attributes of public transport nodes across the city, what tends to allow for accurate computation of transit service density across different residential environments.

Information on formal residential communities was retrieved via Baidu Map API, using web-scraping techniques to extract location and name attributes of residential compounds. This method ensured comprehensive and up-to-date spatial representation of planned residential areas, particularly those registered in formal planning databases. By contrast, urban village data were obtained from the Shenzhen Municipal Planning and Natural Resources Bureau. These data are based on the latest update to the Urban Village Improvement Plan (2021–2025), which delineates the boundary and type of each identified urban village. The dataset includes both original village perimeters and updated versions reflecting urban regeneration progress.

These metrics formed the core of the accessibility indicators used in the subsequent statistical and equity analysis. Additional supporting datasets—such as land-use classifications, road hierarchy, and public facility Points of Interest (POIs)—were considered for contextual understanding but not directly used in quantitative accessibility measures. Future extensions of this research may incorporate POIs (e.g., schools, parks, commercial zones) to evaluate first/last-mile integration and urban vibrancy around residential zones.

3.2. Measuring the variables

3.2.1 Measuring the dependent variable: Spatial equity of public transit station distribution

The dependent variable in this study is the spatial accessibility to public transit stations, measured by the number of metro stations and bus stops within a 100-meter buffer surrounding each residential unit. Residential units were categorized into two types: urban villages and formal residential communities, both represented by polygon geometries derived from municipal planning. For each polygon, a 100-meter

Euclidean buffer was constructed to approximate short-distance pedestrian accessibility.

To evaluate the spatial equity of transit accessibility across these two residential types, we applied spatial autocorrelation methods, particularly Global Moran's I and Local Indicators of Spatial Association (LISA). These methods allow us to assess whether high or low levels of transit accessibility are randomly distributed, clustered, or dispersed across space—and whether such patterns systematically differ between urban villages and formal communities.

3.2.2 Measuring the independent and control variables

The key independent variable is residential typology, operationalized as a binary variable distinguishing urban villages from formal residential communities. This classification is based on morphological, land-use, and administrative attributes identified from Shenzhen's detailed residential land parcel database.

To control for potential confounding factors influencing transit station distribution, we introduced several spatial, infrastructural, and socioeconomic control variables. Spatial controls include residential area size, population density, and land-use diversity within a 500-meter radius. Infrastructural controls include intersection density, presence of dedicated cycling lanes, and road network configuration, all of which may influence walkability and first/last-mile accessibility. Socioeconomic variables, such as rental price levels and migrant population ratios, were integrated to account for differential transit service demand and urban governance priorities. These variables were derived from district-level statistical yearbooks and geo-referenced datasets. Together, these independent and control variables were incorporated into spatial regression models and local spatial statistics to isolate the role of residential typology in shaping the spatial distribution and clustering of transit accessibility.

3.3. Model

The dependent variable of this study is the number of accessible public transit stations (including both metro stations and bus stops) within a 100-meter buffer of each residential unit. Since the dependent variable is non-negative count data and the distribution exhibits overdispersion (variance larger than the mean), we adopted the negative binomial regression model to estimate the relationship between transit accessibility and residential typology as well as other built environment factors (Cameron & Trivedi, 2013).

We specified Yi as the dependent variable, representing the counted number of accessible transit stations for residential unit i, where k takes values {0,1,2,… }. The independent variables include residential typology (urban village or formal community), spatial built environment features (e.g., road intersection density, land-use mix), and socioeconomic indicators (e.g., average rental price, migrant population share). The probability of observing Yi = k given the explanatory variables is expressed as:

$$\Pr(Y_i = k|X_1, X_2, \cdots, X_n) = \frac{\tau(k + \frac{1}{\alpha})}{\tau(k+1)\tau(\frac{1}{\alpha})}\left(\frac{1/\alpha}{1/\alpha + \lambda}\right)^{\frac{1}{\alpha}}\left(\frac{\lambda}{1/\alpha + \lambda}\right)^{Y_i}$$

Where

$$\lambda = E(Y_i) = \exp(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \epsilon)$$

and α is the dispersion parameter controlling for overdispersion. The variance of the dependent variable follows:

$$\mathrm{Var}(Y_i) = \lambda + \alpha\lambda^2$$

which accommodates the observed heterogeneity in the count of accessible stations.

To complement the count-based modeling of accessibility, we further assessed the spatial patterns of transit equity by conducting Global Moran's I and Local Indicators of Spatial Association analyses on the residuals of the regression model. This two-step approach allows us to detect whether spatial clustering of model residuals indicates systematic under- or over-provision of transit access in specific residential types

4. Result and Analysis

4.1. Global Moran's I of Transit Accessibility

The spatial characteristics of transit accessibility in Shenzhen were examined through a comprehensive set of spatial statistical techniques, revealing significant and nuanced patterns of inequality between formal residential communities and urban villages.

The results of the global spatial autocorrelation analysis indicated a strong tendency toward spatial clustering in transit accessibility across the city. Specifically, the Global Moran's I for the minimum distance to the nearest metro station was calculated as 0.439, accompanied by a high z-score of 7.93 and a p-value less than 0.001. This demonstrates a significant positive spatial autocorrelation, implying those residential areas with similar levels of metro accessibility—whether good or poor—tend to be geographically concentrated. A similar pattern was observed in the accessibility to bus stops, where the Global Moran's I reached 0.472 (z-score = 8.57, $p < 0.001$), confirming the existence of spatially clustered areas of both advantage and disadvantage in terms of transit access. These results collectively demonstrate that transit accessibility in Shenzhen exhibits distinct and statistically significant spatial patterns.

4.2. Local Indicators of Spatial Association (LISA) and Hotspot Analysis

Local spatial association was examined using the Local Moran's I (LISA) and Getis-Ord General G statistics, separately applied to formal residential areas and urban villages. In formal residential communities, the spatial distribution of metro stations displayed no significant local clustering, with a Local Moran's I value of 0.000525 ($z = 0.726$, $p = 0.468$), suggesting a largely even spatial pattern.

However, the Getis-Ord General G statistic for the same data revealed significant clustering of high-density metro station areas (General G = 0.333, $z = 2.06$, $p = 0.039$), implying that localized metro accessibility hotspots do exist, particularly in well-planned neighborhoods. In contrast, the spatialdistribution of bus stops in formal communities showed more robust spatial dependence, with a Local Moran's I of 0.002086 ($z = 2.37$, $p = 0.018$), indicating a tendency for similar accessibility levels to cluster together. Nonetheless, the General G value of 0.060 ($z = 1.611$, $p = 0.107$) did not reach statistical significance, suggesting that although clustering occurs, there is a lack of strong, consistent hot or cold spots in bus access.

Urban villages presented a contrasting pattern. The spatial distribution of metro stations around these areas showed moderate, though marginally non-significant, spatial autocorrelation (Moran's I = 0.011876, z = 1.888, p = 0.059), with General G results failing to reach statistical significance (G = 0.000031, z = 1.560, p = 0.119), indicating the presence of uneven and fragmented accessibility but without statistically robust clustering. On the other hand, the spatial pattern of bus stops in urban villages exhibited the most prominent spatial autocorrelation observed in the study. The Local Mor-an's I was 0.0284 (z = 4.373, $p < 0.001$), clearly demonstrating clustered accessibility, albeit without the emergence of dominant hotspots, as suggested by a non-significant General G result (G = 0.00002, z = -0.600, p = 0.549). These findings collectively highlight the highly uneven spatial configuration of transit access in urban villages, particularly in regard to bus infrastructure, where spatial clustering exists but lacks directional intensity in hotspot formation.

These quantitative patterns were confirmed and visualized through the LISA cluster maps and hotspot analysis. For metro access, high-accessibility clusters—reflected by shorter average distances—were heavily concentrated in central districts such as Futian and Luohu, aligning with the city's core transport infrastructure and urban planning priorities. Conversely, areas with poor metro access were typically found in peripheral zones like Longgang and Pingshan, where rapid urban development has outpaced transit infrastructure provision. Bus accessibility exhibited a more fragmented spatial pattern. While high-accessibility clusters appeared in both central areas and some emerging sub-centers such as Nanshan, low-accessibility clusters were mainly located in urban villages on the urban fringe, often spatially isolated from the primary transit network.

Figure 3

Analysis of bus and metro stations surrounding residential communities

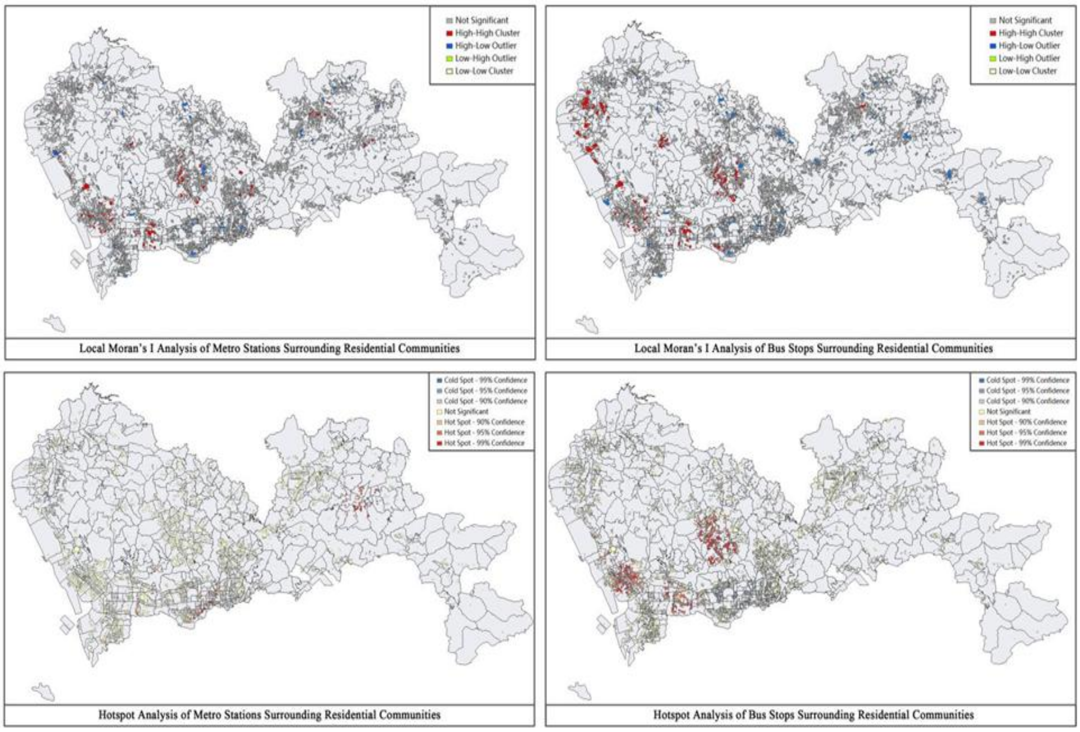
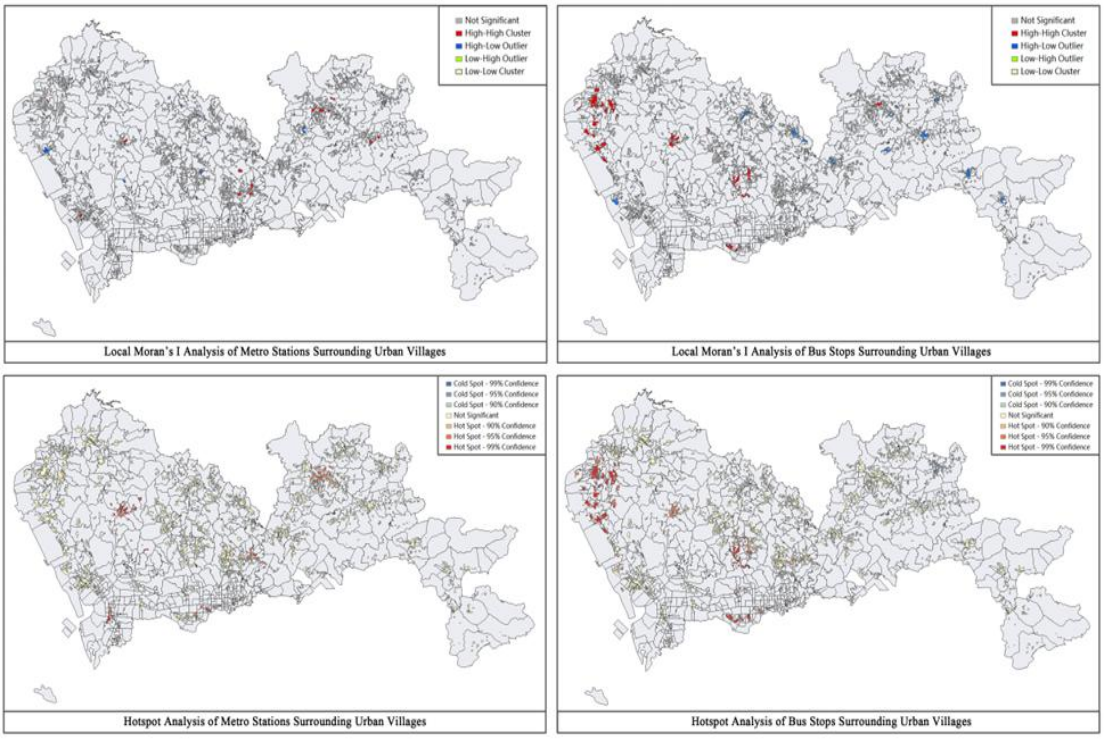


Figure 4

Analysis of bus and metro stations surrounding urban villages



Localized metro accessibility hotspots do exist, particularly in well-planned neighborhoods. In contrast, the spatial distribution of bus stops in formal communities showed more robust spatial dependence, with a Local Moran's I of 0.002086 ($z = 2.37$, $p = 0.018$), indicating a tendency for similar accessibility levels to cluster together.

Nonetheless, the General G value of 0.060 ($z = 1.611$, $p = 0.107$) did not reach statistical significance, suggesting that although clustering occurs, there is a lack of strong, consistent hot or cold spots in bus access.

Urban villages presented a contrasting pattern. The spatial distribution of metro stations around these areas showed moderate, though marginally non-significant, spatial autocorrelation (Moran's I = 0.011876, $z = 1.888$, $p = 0.059$), with General G results failing to reach statistical significance ($G = 0.000031$, $z = 1.560$, $p = 0.119$), indicating the presence of uneven and fragmented accessibility but without statistically robust clustering. On the other hand, the spatial pattern of bus stops in urban villages exhibited the most prominent spatial autocorrelation observed in the study. The Local Moran's I was 0.0284 ($z = 4.373$, $p < 0.001$), clearly demonstrating clustered accessibility, albeit without the emergence of dominant hotspots, as suggested by a non-significant General G result ($G = 0.00002$, $z = -0.600$, $p = 0.549$). These findings collectively highlight the highly uneven spatial configuration of transit access in urban villages, particularly in regard to bus infrastructure, where spatial clustering exists but lacks directional intensity in hotspot formation.

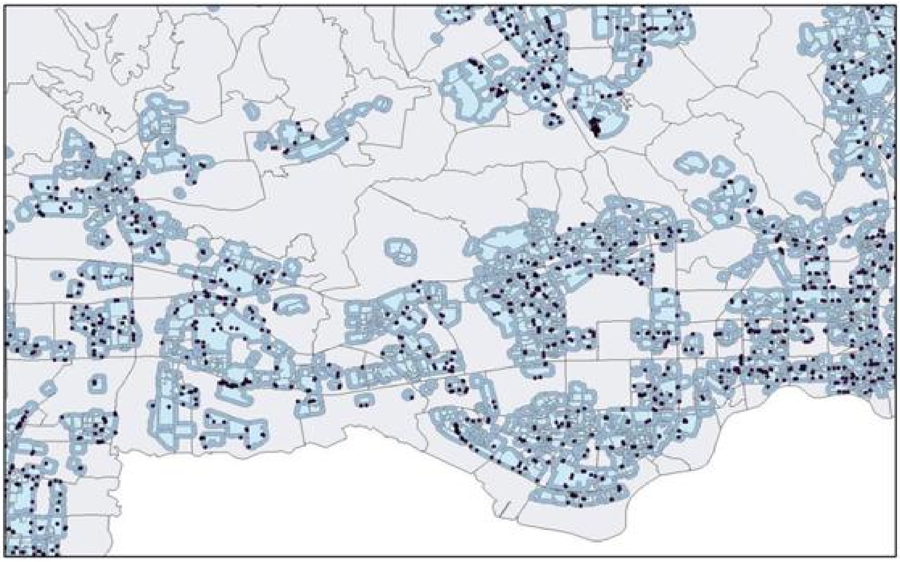
These quantitative patterns were confirmed and visualized through the LISA cluster maps and hotspot analysis (**Figures 3** and **4**). For metro access, high-accessibility clusters—reflected by shorter average distances—were heavily concentrated in central districts such as Futian and Luohu, aligning with the city's core transport infrastructure and urban planning priorities. Conversely, areas with poor metro access were typically found in peripheral zones like Longgang and Pingshan, where rapid urban development has outpaced transit infrastructure provision. Bus accessibility exhibited a more fragmented spatial pattern. While high-accessibility clusters appeared in both central areas and some emerging sub-centers such as Nanshan, low-accessibility clusters were mainly located in urban villages on the urban fringe, often spatially isolated from the primary transit network.

4.3. Buffer Analysis of Transit Infrastructure Density

To further evaluate the spatial configuration of transit infrastructure surrounding different residential typologies, a buffer analysis was conducted. Specifically, 100-meter Euclidean buffers were generated around the polygonal boundaries of both urban villages and formal residential communities (**Figure 5**). This methodological approach enables a more localized and granular assessment of public transit service density in the immediate vicinity of these communities, thereby supplementing spatial statistical outputs such as Local Moran's I.

Figure 5

Bus stops within a 100-meter buffer surrounding residential communities in Futian District



The buffer analysis yielded a clear disparity in the number of public transit facilities within the delineated 100-meter zones. For urban villages, a total of 5,841 bus stops and 423 metro station entrances were identified within the buffer range. In contrast, formal residential communities encompassed 11,839 bus stops and 1,161 metro station entrances within their respective 100-meter buffers. These figures were derived through spatial overlay techniques using high-resolution point data on bus stop and metro entrance locations, intersected with the buffered community boundaries.

These findings reveal a pronounced imbalance in transit service distribution, with formal residential communities demonstrating significantly higher densities of both bus and metro infrastructure within short walking distances. The absolute differences—nearly double in both bus stop and metro entrance counts—suggest a systemic bias in the siting and planning of transit investments, which appear to disproportionately favor formal neighborhoods.

The concentration of transit infrastructure in and around formal residential areas likely reflects broader socioeconomic and institutional dynamics, including planning regimes that prioritize formal development zones. This unequal distribution not only corroborates the patterns identified through geostatistical analysis, but also underscores the spatial manifestations of urban inequality. Residents of urban villages, often characterized by lower socioeconomic status and limited political representation, face reduced physical accessibility to transit services—exacerbating existing disparities in urban mobility and opportunity structures.

5. Conclusion and Policy Recommendations

This study investigated the spatial patterns and disparities in public transit accessibility across different residential typologies in Shenzhen, with a specific focus on formal residential communities and urban villages (Lucas, 2012). By employing a combination of global and local spatial autocorrelation analyses (Global Moran's I and Local Moran's I), as well as buffer and descriptive spatial statistics, this research offers a multi-scalar understanding of transit accessibility and equity in one of China's fastest-growing megacities (Kwan, 2013). The results reveal significant spatial clustering in transit accessibility across the city, with central areas exhibiting higher accessibility levels to both metro stations and bus stops, while peripheral districts—particularly those populated by urban villages—demonstrate significantly lower levels of accessibility. The Local Moran's I and Getis-Ord hotspot analyses further confirm that formal residential areas benefit from more consistent and spatially clustered access to transit services, whereas urban villages exhibit fragmented and statistically less robust patterns of accessibility.

Quantitative comparisons underscore these disparities. Urban villages are located, on average, more than 500 meters farther from metro stations and 120 meters farther from bus stops than their formal counterparts. The buffer analysis further reinforces these findings: within a 100-meter buffer zone, formal residential communities contained nearly twice as many bus stops and almost three times the number of metro station entrances compared to urban villages. These results collectively point to a systematic under-provision of transit infrastructure in areas inhabited by marginalized and socioeconomically disadvantaged populations. The current distribution of public transportation infrastructure appears to reflect planning preferences that prioritize formal residential zones—often better resourced and politically represented—at the expense of informal or semi-formal urban villages.

To address the pronounced spatial disparities in transit accessibility uncovered in this study, a multi-pronged policy approach is necessary—one that combines redistributive infrastructure investment with fine-grained planning tools and socially responsive frameworks. The following recommendations aim to foster a more inclusive, equitable, and integrated urban transit system in Shenzhen and similarly urbanizing contexts.

(1). Redistribute Transit Infrastructure Toward Underserved Peripheral Areas

The clear accessibility gap between formal residential communities and urban villages underscores the need for targeted infrastructure investments. Urban planning authorities should prioritize expanding metro and bus networks in peripheral districts, especially those with high concentrations of urban villages. Improving access in these underserved areas would not only mitigate spatial inequality but also enhance residents' opportunities for employment, education, and public services (Lucas, 2012).

(2). Incorporate Fine-Scale, Community-Level Spatial Assessment Tools

Findings from buffer analysis and Local Moran's I highlight the limitations of relying on course, citywide planning indicators. To better capture local disparities, planning agencies should institutionalize the use of fine-scale spatial analysis tools. These tools can reveal micro-level pockets of transit deprivation, supporting more precise and responsive decision-making in transit provision and urban design.

(3). Institutionalize Buffer-Based Metrics for Targeted Service Improvement

Buffer analysis provides a replicable and intuitive method for assessing transit service intensity around residential areas. Transit authorities should formalize the use of such spatial metrics to guide resource allocation, ensuring that future expansions address real gaps in service provision—particularly in urban villages and other socioeconomically disadvantaged areas.

This study focused primarily on spatial disparities in infrastructure distribution. Future research should incorporate temporal mobility data to examine travel behavior across different residential groups. Additionally, integrating qualitative data—such as resident satisfaction or perceived accessibility—could enrich understanding of the lived experience of transit inequality. Finally, expanding the analytical framework to include other Chinese cities would provide comparative insights and support broader policy generalization.

Acknowledgment: The authors thank the Shenzhen Open Data Platform (transit stations and bus stops), the Shenzhen Municipal Planning and Natural Resources

Bureau (urban-village boundaries), OpenStreetMap (administrative base layers), and the Baidu Map API (residential compound locations) for data support. We also thank colleagues who provided administrative and technical assistance during data cleaning and GIS processing.

Conflict of interest: The author declares no conflict of interest.

References

[1] Ahmed, Q. I., Lu, H., & Ye, S. (2008). Urban transportation and equity: A case study of Beijing and Karachi. *Transportation Research Part A: Policy and Practice*, 42(1), 125–139.

[2] Cameron, A. C., & Trivedi, P. K. (2013). *Regression analysis of count data* (2nd ed.). Cambridge University Press.

[3] Cervero, R., & Day, J. (2008). Suburbanization and transit-oriented development in China. *Transport Policy*, 15(5), 315–323.

[4] Delbosc, A., & Currie, G. (2011). Using Lorenz curves to assess public transport equity. *Journal of Transport Geography*, 19(6), 1252–1259.

[5] Deng, T., & Nelson, J. D. (2013). Bus Rapid Transit implementation in Beijing: An evaluation of performance and impacts. *Research in Transportation Economics*, 39(1), 108–113.

[6] El-Geneidy, A., Levinson, D., Diab, E., Boisjoly, G., Verbich, D., & Loong, C. (2016). The cost of equity: Assessing transit accessibility and social disparity using total travel cost. *Transportation Research Part A: Policy and Practice*, 91, 302–316.

[7] Gao, Y., Liu, K., Zhou, P., & Xie, H. (2021). The effects of residential built environment on supporting physical activity diversity in high-density cities: A case study in Shenzhen, China. *International Journal of Environmental Research and Public Health*, 18(13), 6676.

[8] Handy, S. L., Boarnet, M. G., Ewing, R., & Killingsworth, R. E. (2002). How the built environment affects physical activity: Views from urban planning. *American Journal of Preventive Medicine*, 23(2), 64–73.

[9] Jiao, J., & Dillivan, M. (2013). Transit deserts: The gap between demand and supply. *Journal of Public Transportation*, 16(3), 23–39.

[10] Jing, Y., Liu, Y., Cai, E., Liu, Y., & Zhang, Y. (2018). Quantifying the spatiality of urban leisure venues in Wuhan, Central China–GIS-based spatial pattern metrics. *Sustainable Cities and Society*, 40, 638–647.

[11] Kwan, M. P. (2013). Beyond space (as we knew it): Toward temporally integrated geographies of segregation, health, and accessibility. *Annals of the Association of American Geographers*, 103(5), 1078–1086.

[12] Liu, Y., He, S., Wu, F., & Webster, C. (2010). Urban villages under China's rapid urbanization: Unregulated assets and transitional neighborhoods. *Habitat*

International, 34(2), 135–144.

[13] Lucas, K. (2012). Transport and social exclusion: Where are we now? *Transport Policy*, 20, 105–113.

[14] Lucas, K., Van Wee, B., & Maat, K. (2016). A method to evaluate equitable accessibility: Combining ethical theories and accessibility-based approaches. *Transportation*, 43(3), 473–490.

[15] Martens, K. (2016). *Transport justice: Designing fair transportation systems*. Routledge.

[16] Martens, K., Golub, A., & Robinson, G. (2012). A justice-theoretic approach to the distribution of transportation benefits: Implications for transportation planning practice in the United States. *Transportation Research Part A: Policy and Practice*, 46(4), 684–695.

[17] Pan, H., Shen, Q., & Zhang, M. (2009). Influence of urban form on travel behaviour in four neighbourhoods of Shanghai. *Urban Studies*, 46(2), 275–294.

[18] Wang, D., & Chai, Y. (2009). The jobs–housing relationship and commuting in Beijing, China: The legacy of Danwei. *Journal of Transport Geography*, 17(1), 30–38.

[19] Wu, F., Zhang, F., & Webster, C. (2013). Informality and the development and demolition of urban villages in the Chinese peri-urban area. *Urban Studies*, 50(10), 1919–1934.

[20] Xu, J., & Yeh, A. G. (2005). City repositioning and competitiveness building in regional development: New development strategies in Guangzhou, China. *International Journal of Urban and Regional Research*, 29(2), 283–308.

[21] Xu, W., Guthrie, A., Fan, Y., & Li, Y. (2017). Transit-oriented development in China: Literature review and evaluation of TOD potential across 50 Chinese cities. *Journal of Transport and Land Use*, 10(1), 743–762.

[22] Yang, W., Chen, B. Y., Cao, X., Li, T., & Li, P. (2017). The spatial characteristics and influencing factors of modal accessibility gaps: A case study for Guangzhou, China. *Journal of Transport Geography*, 60, 21–32.

[23] Zhang, M., & Kukadia, N. (2005). Metrics of urban form and the modifiable areal unit problem. *Transportation Research Record*, 1902(1), 71–79.