Spatial Scale Effects of Land-use Mix around Rail Transit Stations: A Comparative Study Based on Three Typical Stations in Chaoyang District, Beijing

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Abstract With the continuous development of rail transit networks, increasing attention has been paid to the impact of land-use mix around rail transit stations on residents' travel behavior and urban spatial organization. This study focuses on Wangjing Station, Sanyuanqiao Station, and Guomao Station in Chaoyang District, Beijing. Based on point-of-interest (POI) data from Baidu Maps in 2025, land-use functions around the stations are classified into six categories: commerce, catering, office, entertainment, residence, and public services. Multi-scale cumulative buffer zones with radii ranging from 100 to 1,000 m are constructed, and normalized Shannon entropy is used to measure the degree of land-use mix at different scales. The results indicate that the degree of land-use mix at all three stations exhibits significant spatial scale dependence, and there are differences in the characteristics of changes; the highest degrees of land-use mix occur at scales of 300, 400, and 1,000 m. An increase in the number of POIs does not necessarily mean a synchronous improvement in the degree of land-use mix. Therefore, the evaluation of land-use functions around rail transit stations should be based on the functional structure and spatial scale characteristics of different sites, and differentiated spatial optimization strategies should be adopted.

Keywords Rail transit stations, Land-use mix, POI, Spatial scale, Shannon entropy

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With the continuous development of the rail transit network, rail transit stations have gradually transformed from single transportation facilities into important nodes for urban public activities and spatial organization. Land use and functional configuration around the stations not only affect the concentration of rail transit passenger flows, but also are closely related to residents' walking, public transportation transfers, and daily activities. Cervero et al.[1] found that built environment characteristics, such as land-use mix, density, and street design, are associated with walking and travel behavior. The degree of land-use mix is commonly used to characterize the extent to which different urban functions coexist within a given spatial area.

In previous studies, assessments of land use around rail transit stations have often adopted a predetermined radius, such as 300, 500, or 800 m. However, spatial functions around stations do not necessarily vary according to fixed distance thresholds, and different types of stations may exhibit differences in functional agglomeration, dispersion, urban road networks, and parcel configurations. Assessments conducted at a single spatial scale may therefore fail to accurately capture the spatial characteristics of land-use mix around rail transit stations.

Therefore, the focus of this paper shifts from "the degree of land-use mix at a fixed scale" to "how the degree of land-use mix varies with distance, and whether different sites have different characteristic scales". In this paper, Wangjing Station, Sanyuanqiao Station, and Guomao Station in Chaoyang District, Beijing are selected as typical cases. Multi-scale cumulative buffer zones with radii ranging from 100 to 1,000 m are constructed around the stations. POI data are used to identify the functional composition of the areas surrounding the stations, and normalized Shannon entropy is employed to calculate the degree of land-use mix at different spatial scales.

1 Research foundation

1.1 Overview of the research subject

In this paper, Wangjing Station, Sanyuanqiao Station, and Guomao Station in Chaoyang District, Beijing are selected as case study sites. Wangjing Station is a transfer station for Metro Line 14 and Line 15, located in the core area of Wangjing. The surrounding area is mainly composed of residential, commercial, and multifunctional land, exhibiting the characteristics of a TOD model featuring jobs–housing integration and coordinated industrial and urban development. Guomao Station is a transfer station between Line 1 and Line 10, and is the core hub of Beijing CBD. It is surrounded by Grade A office buildings, high-end businesses, and hotels, and is a typical employment-center-oriented TOD with extremely high development density. Sanyuanqiao Station is an interchange station serving Metro Lines 10 and 12 and the Capital Airport Express, adjacent to the Third Embassy District. The surrounding land is mainly used for business offices, commercial facilities, and residential purposes, with dual attributes of transportation gateway and foreign-related business. The three sites represent three different TOD development models: new areas characterized by urban–industrial integration, urban employment centers, and comprehensive transportation hubs, providing ideal samples for comparative research.

1.2 Research ideas

Ten cumulative buffer zones, with radii of 100, 200, 300, ⋯, and 1,000 m, are established around each of the three rail transit stations: Wangjing Station, Sanyuanqiao Station, and Guomao Station. Specifically, each buffer zone represents the cumulative functional composition within its corresponding radius from the station. For example, the 100 m buffer zone covers the area within 100 m of the station, whereas the 200 m buffer zone covers the area within 200 m. By classifying POI data within the region, the degree of land-use mix within each buffer zone is measured, and how the overall degree of land-use mix changes as the site research scope expands is observed.

1.3 Research methods

In this study, the entropy index is used to measure the degree of land-use mix around the three stations. Previous studies have commonly employed heterogeneity indices, such as the

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Shannon entropy index, the Shannon–Wiener index, and the Simpson index, to quantitatively characterize land-use mix[2-5]. Cervero first applied the entropy index to measure the degree of land-use mix, measuring the balance of land use within a region through the proportional relationship between different land use types[6]. The specific calculation formula is as follows:

$$E=\frac{-\sum(A_{ij}\ln A_{ij})}{\ln N_j} \quad (1)$$

where A_{ij} is the proportion of land-use type i within spatial unit j (%); N_j is the number of land use types within spatial unit j.

The range of entropy values is [0, 1]. When there is only one type of land use in the region, the entropy value is 0; when the proportion of various land uses in the region is equal, the entropy value is 1. A higher value indicates a more balanced distribution of land-use types.

1.4 Research data

This study primarily uses POI data obtained from Baidu Maps in 2025. These data provide detailed information on the spatial distribution of urban facilities and service functions and are well suited to identifying urban functions and analyzing the built environment. Based on the functional characteristics of the areas surrounding the selected stations, POIs are classified into six categories: commerce, catering, office, entertainment, residence, and public services (Table 1).

2 Results and analysis

2.1 Wangjing Station

The degrees of land-use mix at different scales around Wangjing Station are 0.613 1, 0.799 5, 0.861 1, 0.791 0, 0.850 2, 0.848 0, 0.844 1, 0.857 4, 0.815 6, and 0.830 6, respectively. Among the spatial scales examined, the scale of 100 m has the lowest degree of land-use mix, only 0.613 1. As the research scope expands, the degree of land-use mix rapidly increases, reaching a maximum value of 0.861 1 at 300 m (Fig.1). This result suggests that land-use mix around Wangjing Station reaches its highest level at the 300 m scale within the range examined. As the buffer radius increases, a wider range of land-use functions is encompassed, and the distribution of different functional types tends to become more balanced. However, the degree of land-use mix decreases to 0.791 0 at the 400 m buffer radius, before recovering and remaining relatively high between 500 and 800 m. This pattern indicates that the degree of land-use mix does not increase continuously with the expansion of the buffer radius but instead exhibits considerable fluctuations across spatial scales. For Wangjing Station, a buffer radius of 300 m can be regarded as a characteristic scale

Table 1 Classification of POI interest points

Type	Secondary type	Specific POI facilities
Commerce	Shopping mall	Shopping malls, shopping centers, and commercial complexes
	Supermarket	Large supermarkets, chain supermarkets
	Retail	Convenience stores, clothing stores, digital stores, home furnishing stores, etc.
	Professional market	Building materials market, agricultural market, wholesale market
	Business services	Beauty salon, laundry, maintenance, etc.
Catering	Main meal	Chinese cuisine, Western cuisine, Korean cuisine, Japanese cuisine, etc.
	Fast food	Fast food restaurants, hamburgers, noodles, etc.
	Drinks	Coffee, milk tea, tea drinks
	Snack	Snack shops, barbecues, local specialties
	Other catering establishments	Restaurants
Office	Office building	Office building, office block
	Enterprise	Company, corporate headquarters
	Technology parks and innovation parks	Technology park, industrial park, innovation park
	Business services	Law firms, accounting firms, consulting firms
	Finance	Banks, securities, insurance, funds, etc.
Entertainment	Cinema	Cinema
	KTV	KTV, large-scale karaoke venues
	Entertainment	Game halls, internet cafes, board games, escape rooms
	Leisure	SPA, foot massage, leisure club
	Tourism	Scenic spots, parks, amusement parks
	Culture and entertainment	Theater, performing venue
Residence	Residential community	Residential community, residential area, community
	Apartment	Apartments, long-term rental apartments, youth apartments
	Dormitory	Student dormitories, staff dormitories
	Residential supporting facilities	Supporting facilities within the community
Public services	Education	Kindergartens, primary schools, secondary schools, universities, training institutions
	Medical treatment	Hospitals, clinics, and community health service centers
	Administration	Government, street offices, community service centers
	Culture	Libraries, cultural centers, museums
	Sports	Gymnasium, sports stadium, public fitness facilities
		Nursing homes, community service centers, social welfare institutions

at which the degree of land-use mix reaches its highest value within the range examined in this study.

2.2 Sanyuanqiao Station

The degrees of land-use mix at the scale of 100−1,000 m at Sanyuanqiao Station are 0.602 2, 0.636 3, 0.744 5, 0.822 5, 0.820 4, 0.811 8, 0.794 4, 0.794 5, 0.810 4, and 0.822 4, respectively. Compared with Wangjing Station, Sanyuanqiao Station exhibits a more gradual increase in the degree of land-use mix between buffer radii of 100 and 300 m, rising from 0.602 2 at 100 m to 0.744 5 at 300 m. At a buffer radius of 400 m, the degree of land-use mix rises sharply to 0.822 5, reaching the highest value within the range of spatial scales examined in this study. Subsequently, the degree of land-use mix decreases slightly between buffer radii of 500 and 800 m, before recovering at 900 and 1,000 m (Fig.2). This pattern suggests that, compared with Wangjing Station, the degree of land-use mix around Sanyuanqiao Station is better captured at a relatively larger spatial scale.

2.3 Guomao Station

The degrees of land-use mix at the scale of 100−1,000 m at Guomao Station are 0.602 2, 0.649 9, 0.776 8, 0.800 4, 0.807 9, 0.804 4, 0.805 7, 0.810 3, 0.809 9, and 0.815 2, respectively. There are certain differences in the changing characteristics of Guomao Station compared to the first two stations. The degree of land-use mix gradually increases from 0.602 2 at 100 m, remains above 0.80 after reaching 0.800 4 at 400 m, and reaches the highest value of 0.815 2 at 1,000 m (Fig.3). Compared with Wangjing Station reaching its peak at 300 m and Sanyuanqiao Station reaching its peak at 400 m, Guomao Station does not show obvious local peaks in the small and medium scale range, but maintains a high level in a larger research area. From the perspective of functional structure, the area surrounding Guomao Station exhibits a pronounced concentration of office, catering, and commercial functions. As the buffer radius increases, a wider range of land-use functions, including residential, public service, and entertainment functions, is encompassed within the study area. This broader functional representation tends to produce a more balanced distribution of functional types, thereby contributing to a higher degree of land-use mix at larger spatial scales.

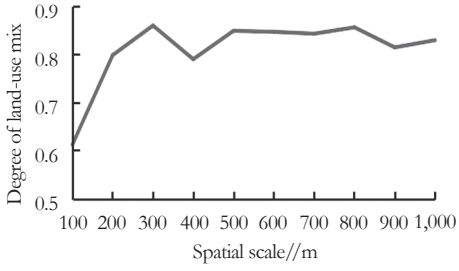

Fig.1 Land-use mix around Wangjing Station

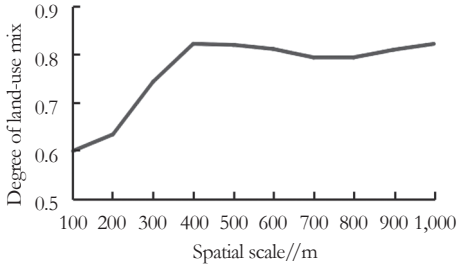

Fig.2 Land-use mix around Sanyuanqiao Station

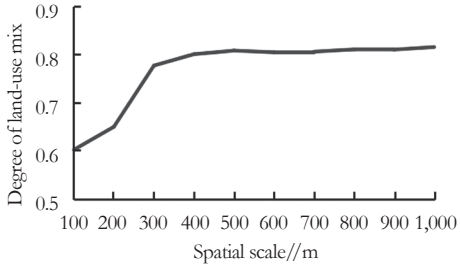

Fig.3 Land-use mix around Guomao Station

Table 2 Comparison of land-use mix across the three stations

Station	Maximum mixing degree	Corresponding scale//m
Wangjing	0.861 1	300
Sanyuanqiao	0.822 5	400
Guomao	0.815 2	1,000

3 Comparison of scale effects at different stations

The measurement results of three sites show that degree of land-use mix has significant spatial scale dependence. The highest mixing degree of the three sites appears at 300, 400 and 1,000 m, respectively, forming significant scale differences (Table 2).

First, the three study sites exhibit distinct patterns of variation in the degree of land-use mix across spatial scales. At Wangjing Station, the degree of land-use mix fluctuates after reaching a peak at 300 m. At Sanyuanqiao Station, it declines slightly after peaking at 400 m. In contrast, Guomao Station exhibits an overall upward trend in the degree of land-use mix as the buffer radius increases.

Secondly, there is no simple positive correlation between degree of land-use mix and the number of POIs. As the buffer radius expands from 100 to 1,000 m, the number of POIs at each site significantly increases, but the degree of land-use mix does not continue to improve synchronously. This is because Shannon entropy focuses not on the number of facilities themselves, but on the relative balance between different functional types. When new POIs are mainly focused on existing advantageous functions, even if the total number of POIs increases, it may lead to a decrease in degree of land-use mix.

The findings of this study highlight the limitations of conventional station-area assessment methods that rely on fixed-radius buffers. Cervero et al.[1] in their study of the relationship between transportation and the built environment, also emphasized the importance of considering land-use density and diversity in the context of specific built environments. Therefore, studies assessing land use around rail transit stations should not assume that all stations have the same spatial extent of influence.

4 Conclusions

Based on POI data from Wangjing Station, Sanyuanqiao Station, and Guomao Station in Chaoyang District, Beijing, ten cumulative buffer zones with radii ranging from 100 to 1,000 m were constructed around each station. The normalized Shannon entropy is used to measure the degree of land-use mix around the stations, with a focus on analyzing their spatial scale effects.

The results of this study show that: firstly, land-use mix around rail transit stations exhibits pronounced spatial scale dependence, with the degree of land-use mix at the three stations displaying varying patterns of nonlinear variation as the buffer radius increases. This indicates that land-use mix is not a fixed spatial attribute but varies across spatial scales. Secondly, the three study sites exhibit distinct characteristic spatial scales of land-use mix, with the highest degree of land-use mix occurring at buffer radii of 300, 400, and 1,000 m for Wangjing Station, Sanyuanqiao Station, and Guomao Station,

(To be continued in P23)

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respectively. This suggests that applying a uniform spatial radius of influence to all stations may obscure differences in their functional spatial characteristics. Thirdly, an increase in the number of POIs does not necessarily correspond to an increase in the degree of land-use mix. There are certain differences in functional scale and balance, and the number and structure of functions should be comprehensively considered. Fourthly, spatial planning around rail transit stations should move beyond a uniform buffer-radius approach. Instead, differentiated functional layouts and spatial optimization strategies should be developed based on the functional structure and characteristic spatial scales of individual stations.

This study has several limitations. First, POI data primarily reflect the distribution of facilities and service functions and cannot be directly equated with land-use area. Second, although cumulative buffer zones capture changes in land-use mix across different spatial scales, they do not adequately reveal functional variations within individual distance bands. Future research could therefore adopt ring-based spatial analysis and incorporate multi-source data, including land-use data, building function data, and population activity data, to validate the findings. In addition, expanding the sample of rail transit stations could improve the robustness of characteristic spatial scale identification and enhance the generalizability of the research findings.

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