Evaluation of Urban Rail Transit Station Effectiveness Based on TOD Principle -Taking Shanghai as an Example

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Abstract. The rapid development of China's cities has led to a variety of traffic problems. Building a public transportation-oriented urban space development model and playing the role of rail transit in urban development are important measures for the upgrading and construction of China's cities. In order to evaluate the development effect of TOD mode of existing rail transit stations, this paper combines the concept of TOD development and 5D principles to establish a set of urban rail transit station effectiveness evaluation index system, determines the four first-level indicators and 13 second-level indicators based on transportation, society, economy and environment, uses the analytic hierarchy method to determine the weights, and analyzes 30 stations of Shanghai Metro Line 2 as a case study.Based on the Arcgis spatial analysis technology, the data is organized and the indexes are calculated. The sites with the strongest TOD ability are Nanjing East Road and Jing'an Temple, the worst sites are Pudong International Airport and Haitian Third Road, their gap mainly lies in the level of economic development around the stations and the degree of crowd gathering,and finally the paper combined with the evaluation results to give development suggestions, this method can be used to study the level of development of rail transit stations in different cities and different regions. This method can be used to study the development level of rail transit stations in different cities and regions, and give suggestions for improving the TOD situation of stations.

Keywords: TOD mode; the Analytic Hierarchy Process; evaluation index; Arcgis; urban development.

1. Introduction

1.1. Research Background

Due to China's rapid economic development, accelerating urbanization, the gradual emergence of the small car as a member of family life, and the increasing intensity of motorized travel have led to the emergence of a variety of urban problems. Urban transportation is the foundation of urban development. Problems such as traffic congestion, traffic accidents, environmental pollution, and financial confusion in its construction will seriously hinder the productivity and future development of modern cities.

In order to make traffic construction promote urban development instead of restricting its progress, it is necessary to find a development model suitable for the coordination of traffic and cities in our country. China's "Outline for the Construction of a Powerful Transportation Country" specifies "constructing an integrated transportation network of urban agglomerations and promoting the integrated development of urban rail transit", conceiving rail transit to optimize the urban structure. High-efficiency public transportation effectively alleviates the crowded passenger flow in the city, constitutes the center of urban construction, and becomes a trend-setter in urban development.

1.2. Proposal of the TOD concept

The form of land use directly affects the fundamentals of urban transportation, which is related to urban traffic generation, traffic distribution, traffic volume and transportation mode, and is the carrier of various economic, social and cultural activities in cities. In order to solve the problem of "urban disease", which is the infinite spread of suburbanization in the United States after World War II, Calthorpe proposed a model of coordinated development between transportation construction and land development - the public transportation-oriented urban spatial development (TOD). This concept has been widely recognized and applied worldwide, and plays a significant role in solving the imbalance between land use and transportation due to rapid urban development today.

TOD emphasizes the interdependence of the public transportation system and urban construction, and advocates that residents give priority to public transportation for travel. It develops land in a high-density and high-utilization way to optimize the layout and design of the transportation system to achieve sustainable urban development and comprehensive improvement of social benefits. It can realize the connection of all areas of the city with comfortable pedestrian space, and achieve a high degree of harmony and unity among urban production, life and ecology.

1.3. TOD Effectiveness

The development is based on the unique "5D" principle of TOD, which promotes the convenience of life. The role played by the TOD model in urban construction has achieved small results in my country: reducing the frequency of car travel, providing a comfortable walking area, and being oriented by public transportation High-quality rail transit can effectively release urban traffic pressure; first plan traffic construction, and then promote urban construction, making land development more intensive and reconstructing urban form; TOD can save travel costs for travel users, and obtain service providers with less investment Substantial output can drive economic development and improve urban traffic efficiency for the society; TOD implements green development, reduces motor vehicle pollutant emissions, protects the environment, curbs urban sprawl, and reduces urban noise. All in all, the development of urban construction in the TOD mode has great advantages in terms of economy, environment, and society, and is an important measure for the development of transportation construction at present.

2. Review of the literature

2.1. Status of foreign research

The concept of TOD originated in the United States, where the urban design movement with the slogan "New Urbanism" was introduced to address the decline of urban functions caused by suburbanization, and the TOD development model began to operate.

The TOD concept was first proposed by Peter Calthorpe as an alternative to suburban sprawl, and developed a set of detailed and specific guidelines for various urban land uses based on the TOD strategy [1], which can be understood as linking different land uses through urban centers to gain employment and services and improve urban attractiveness [2]. Robert Cervero and Kara Kockelman proposed the "3D" principle of TOD theory - Density, Diversity, and Design - and used it to propose the TOD model. Mackett and Edwards (1998) conducted an international study to highlight the benefits of rail transit. They argued that urban rail transit can improve the overall public transportation system, reduce traffic congestion, better serve downtowns, improve the environment, and stimulate economic development [4]. In addition, transportation infrastructure investments affect mobility and may have a significant impact on the capitalization of areas surrounding these infrastructure projects even before they are completed [5]. The impact of a subway system with TOD features on the share of car and bus trips, ranges from neutral to positive, suggesting that buses and subways complement each other rather than compete for ridership [6] In terms of TOD evaluation indicators, Robert Cervero identified several indicators such as land use, parking size, and site development density [7].

2.2. Status of domestic research

Since the reform and opening up, China introduced the TOD model in the late 1990s by learning from the experiences of Japan, Hong Kong, China, and other regions in TOD and urban renewal. For the study of TOD indicators, Zhang Jun established a group of 36 project indicators targeting the sustainable development level of cities in 2007 [8]. Kong Lingqi of Chang'an University proposed that the development of TOD in China needs to distinguish between old and new urban areas, and closely integrate public transportation and urban development from three levels: macro, meso and micro [9]. Lei Fu studied the urban layout pattern of Chengdu city, analyzed the transportation characteristics and demand of corridor structure, and pointed out that large cities should use rail transit as the leading tool for the development of large cities in China [10]. Weixiu Wang took Shijiazhuang metro phase I project as an example and used the projection tracing model to effectively estimate the comprehensive benefit value of the rail transit project [11]. Starting from the connotation of transit-led urban transportation mode, Jingwen Han analyzed the key indicators affecting the effectiveness of transportation system in five aspects, established a set of evaluation system for the effectiveness of transit-led urban transportation system, and implemented the evaluation function based on TranStar software platform [12]. The evaluation system based on the development principles of TOD has also been explored. Zhu Chao proposed a framework and principle method for the construction of a comprehensive evaluation index system of TOD, and used the expert research method and the great irrelevance method as well as the typical index method to select TOD evaluation indexes [13]. Yao La's advanced experience in TOD and urban renewal proposed to establish the guiding ideology and countermeasure suggestions for promoting high-quality development of urban renewal with TOD as the leader [14].

3. Research Methodology

3.1. Research Subjects

Shanghai is the central city of China, with an administrative area of 6340.5 square kilometers and 16 districts under its jurisdiction. At the end of 2022, the resident population of Shanghai is 24,758,900 people. Since the construction of Line 1 started in 1993, by the end of 2022, Shanghai's rail transit network will have increased to 831 km, 20 lines, 508 stations and 83 interchange stations, leading the world in terms of network size. Figure 1 shows the existing Shanghai rail transit network system.

The "14th Five-Year Plan for Shanghai's Comprehensive Transportation Development", published by the Shanghai Municipal Government in 2021, emphasizes station-city integration as a more specific requirement for metro station construction, emphasizing the construction of systems and integrated transportation systems for new cities to achieve internal high-quality transportation. However, the performance and type of stations vary greatly, as does the surrounding land use and morphology. Local governments have introduced the TOD concept into land use planning and have adopted TOD as a key strategy for sustainable urban development. In addition, Shanghai has developed a digital transformation plan with the goal of becoming a global digital capital by 2035, so there is an urgent need for a method to systematically measure the effectiveness of TOD.

Shanghai Metro Line 2, the second metro line operating in Shanghai, is the busiest and most important artery of Shanghai's rail transportation, with a total length of 64 km and 30 stations, including 2 elevated stations, 1 above-ground station and 27 underground stations, running through the east-west axis of Shanghai, is one of the most powerful metro lines in Shanghai, also known as Golden Line 2, and has been the first in Shanghai in terms of passenger density. As there are many ground and elevated sections throughout the line, it is a more comfortable experience for passengers than the long underground sections, and the routes of Line 2 are basically the most promising prime locations in Shanghai: Puxi side representatives - Zhongshan Park, Jiangsu Road, Jing'an Temple, Nanxi, and Renguang; Pudong side representatives - Lujiazui, Century Avenue, and Lujiazui. -Line 2 runs through the core business district of Shanghai South Jing'an and the northern part of Huangpu District, the highest level of cbd Lujiazui, and connects the two airports, this proximal advantage of all lines in Shanghai can not find a second, Line 2 also has the advantage of interchange, except Line 5 and Pujiang line can be changed to. For its advantages, the problem of travel restriction during peak hours and its impact on Shanghai traffic, we take the stations along Metro Line 2 as the object of study. Figure 1 shows the operation of Shanghai metro.

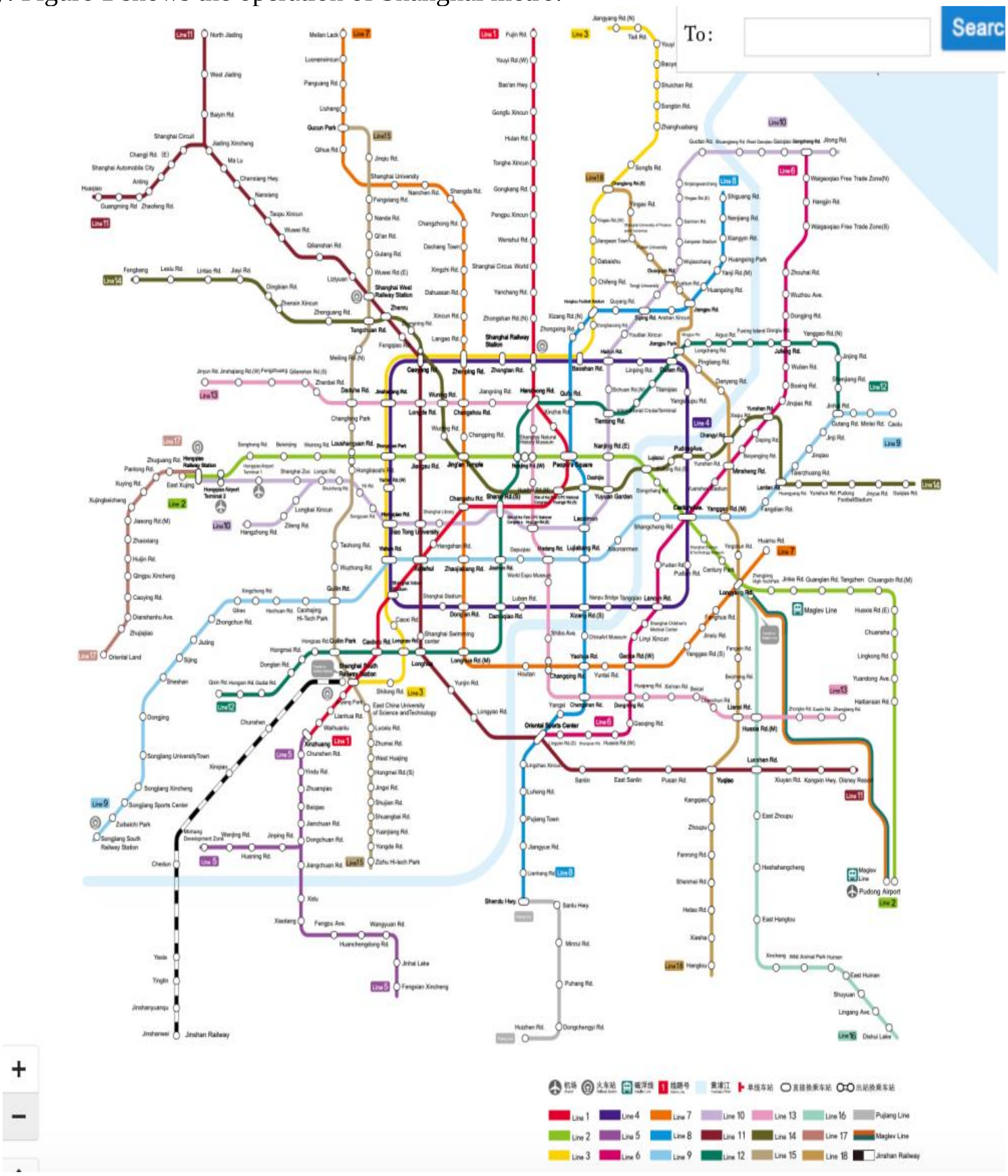

Fig. 1 Shanghai Metro Operation Diagram

3.2. Evaluation Method

3.2.1 Evaluation indicators

Based on Bertolini's Node-Place principle, which emphasizes that stations need to have the dual characteristics of traffic nodes and spatial places, and the 5D principle introduced in the previous paper, integrating the concept of TOD development, through a large number of literature studies and summaries, this paper will conduct a comprehensive analysis from four aspects: traffic benefits, social benefits, economic benefits, and environmental benefits. Table 1 shows the evaluation index body of urban rail transit station effectiveness based on the TOD principle.

Table 1 Site effectiveness evaluation index selection

Site TOD development	
Transportation Benefits A1	Accessibility (A11) Subway Frequency(A12) Bus Station Density(A13) Parking Lot Density(A14) Average Daily Passenger Traffic(A15)
Economic Benefits A2	Housing Price Per Unit Area (A21) Commercial Area Coverage(A22) Residential Area Coverage(A23)
Social Benefits A3	Land Use Diversity(A31) Population Density(A32) Accessibility of Living Facilities(A33)
Environmental Benefits A4	Greenery Coverage(A41) Air Quality Index(A42)

3.2.2 Indicator Meaning

The analysis and understanding of the selected indicators are shown in Table 2.

Table 2 Meaning of indicators

Guideline layer	Indicator Name	Meaning
Traffic efficiency indicators	Accessibility of subway stations	The accessibility of subway stations refers to the ease of reaching one station from another. The accessibility of metro stations varies depending on the size of the station and the degree of development of the surrounding land.
	Subway Frequency	The frequency of trains during off-peak hours at stations on weekdays, the number of subway frequencies can indicate the size of a subway station and describe the station's accessibility to rail transit and the surrounding environment.
	Bus stop density	Passengers using rail transportation usually choose to interchange with public transportation to reach their destinations. Bus stop density can be used to measure the development level of public transportation around a TOD station, and is an important indicator to evaluate the reasonableness of the traffic structure around the station area. The greater the number of interchangeable bus stops and the greater the convenience of interchangeability, the better the traffic efficiency of the station.
	Parking density	Considering the density of parking lots near the TOD station area is an important factor that can indicate the convenience of traveling to the station by car.
	Average daily passenger volume	Station area with TOD development mode affects passenger traffic, the higher the accessibility around the TOD station, the more optimized the policy, the better the average daily passenger traffic of the station with mixed land type.
Economic efficiency indicators	Unit area house price	According to past real estate statistics around TOD sites, generally speaking, the more mature TOD mode development sites, the greater the land appreciation, the higher the average price of housing transactions will be.
	Commercial service coverage rate	Under the TOD model, the land allocation and land use around the rail transit stations are coordinated and influenced by the principle of "high density", and commercial services can drive the commercial process in the city and drive the economic benefits around the stations.
	Business office coverage	TOD site annex is a comprehensive community, commercial and office services are extremely important, but the coverage of office and commercial area should be moderate, not overly commercial and not closed.
Social benefit indicators	Land use diversity	The promotion of mixed land uses within the rail station area is encouraged, allowing for a mix of commercial, travel, recreational, and residential land uses. The diversity of land development will gradually make residents less dependent on cars or evolve to travel shorter distances to their destinations and serve different groups of people, making "diversity" more comprehensive and specific.
	Neighborhood Coverage	The walking distance between the residents around the TOD station and the station is within 10 minutes, which is an efficient travel distance. The coverage rate of the residential area around the station can measure whether the station development mode is convenient for the residents and whether it reflects the human-friendly purpose of the TOD mode.
	Accessibility of living facilities	TOD mode around the station area can be a one-stop integration of work, consumption, living, medical and other facilities, which can greatly improve the quality of life and travel friendliness.
Environmental benefit indicators	Greening coverage rate	The level of green area within the rail transit station can reflect the environmental friendliness in TOD mode, which greatly promotes sustainable urban development and the integration of travel and environment.
	Air Quality Index	The value that integrates the air pollution status and the overall air quality level. It is suitable for indicating the short-term air quality condition and change trend in the station area under the TOD model.

3.2.3 Evaluation Method

The Analytic Hierarchy Process (AHP) is a decision evaluation method that can combine qualitative and quantitative analysis, compare indicators two by two, and get the importance multiplier between indicators. It embodies the basic characteristics of human decision-making thinking, i.e. decomposition, judgment and synthesis, overcoming the shortcomings of the rest evaluation methods that do not consider the subjective judgment of decision makers. When dealing with complex problems, it is often necessary to establish a mathematical model, decompose the complex problem into simple sub-problems, establish a recursive hierarchy, transform human judgment into a quantitative comparison calculation of the relative importance of two-two indicators at each level, calculate the relative importance values of all factors at each level using mathematical methods, and finally analyze and propose a practical solution to the problem.

Steps of hierarchical analysis:

(1) Establishment of recursive hierarchy:

The establishment of indicator system is the premise of urban rail station effectiveness evaluation. Based on the principles of systemic, generality, comparability and operability, a three-layer tower structure evaluation system is constructed based on TOD principles and concepts. The target layer (T) is the development level of site TOD, and the criterion layer (A) is the traffic effectiveness (A1), economic effectiveness (A2), social effectiveness (A3) and environmental effectiveness (A4). The indicator layer, i.e., each specific indicator for specific evaluation, is accessibility (A11), metro frequency (A12), bus station density A(13), parking density A(14), average daily passenger volume (A15), unit area house price (A(21), commercial service coverage (A22), business office coverage (A23), land use diversity A(31), residential area density (A32), accessibility to amenities (A33), greenery coverage (A41), and air quality index (A42). According to the indicator system obtained from the above analysis, a hierarchical structure model can be drawn:

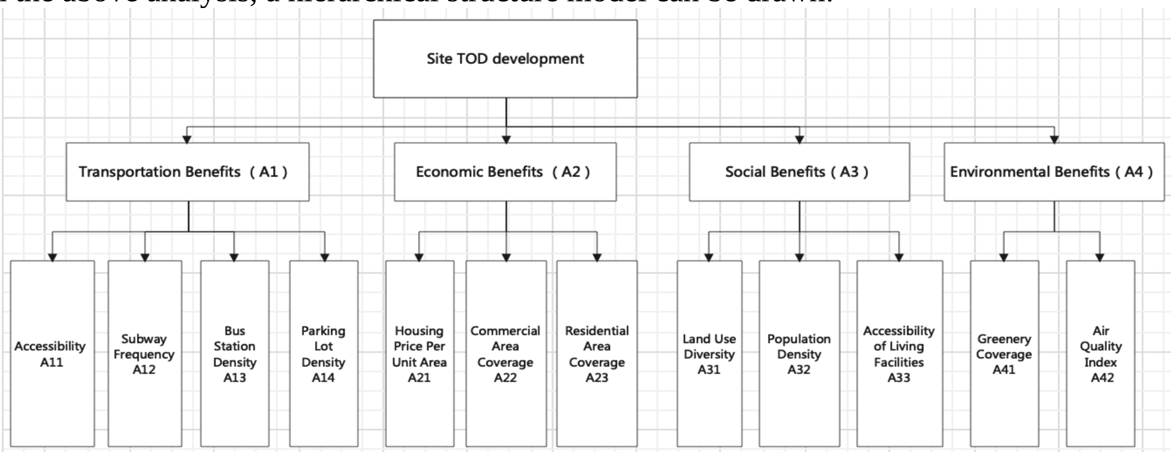

Fig. 2 Hierarchy model diagram

(2) Construction of judgment matrix:

In each level, if several elements are related to a certain element in the previous level, the relative importance of each factor in the same level is determined by a two-by-two comparison; the program level is also used as a level. To construct the judgment matrix, we need to introduce the "1-9" scale method, see Table 3.

Table 3 "1-9" scale method

A:B	Meaning
1	Element A is of equal importance to element B
3	A is slightly more important than B
5	A is significantly more important than B
7	A is strongly more important than B
9	A is more extremely important than B
Countdown	Element A is less important than element B
2, 4, 6, 8	Intermediate value of the above adjacent judgments

(3) Calculate the weights of the evaluation criteria:

AW = λW obtained by solving the following eigenvalue problem, where W is a vector and

$$W = (W1W2 \ldots \ldots Wn)r, \quad (1)$$

λis the eigenroot of the judgment matrix A, and W is the eigenvector corresponding to the eigenroot. Calculate the maximum characteristic root of the judgment matrix:

$$\lambda_{max} = \sum_{i=1}^{n} \frac{AW_i}{nW_i} \quad (2)$$

where AW_i denotes the i-th element of vector AW, and the component W_i of W is the weight value of the corresponding element ordering.

(4) Consistency test of the judgment matrix:

The comparison matrix of different stages should be consistent, and consistency test should be performed to determine whether the matrix is logically reasonable. The more elements, the more prone to errors and the more tolerant the requirements for judgment consistency errors. In order to reasonably evaluate whether the consistency of the judgment matrix of different orders meets the requirements, the average random consistency index R.I. is introduced

$$CR=CI/RI, \quad (3)$$

Where CR is the consistency value. When $CR<0.1$, it can be determined that the matrix is acceptable; otherwise, the comparison distance array needs to be revised until $CR<0.1$ is satisfied,

$$CI=(\lambda_{max}-n)/(n-1) \quad (4)$$

In the formula:

CI--indicates the consistency index.

λ_{max}--- denotes the maximum characteristic root of the judgment matrix.

n--indicates the number of comparison factors.

RI--indicates the random consistency index.

(5) Calculate the comprehensive weight value.

4. Study Results

4.1. Quantitative results of indicators

4.1.1 Traffic efficiency indicators

(1) Accessibility of metro stations

The accessibility of metro stations in the study area to other locations is expressed by the metro lines connected to the metro stations, which is calculated in this paper by the latest metro lines announced on the official website of Shanghai Metro.

(2) Subway frequency

The metro frequency indicates the number of metro trains passing through the station per hour, which is calculated by the metro frequency published on the official website of Shanghai Metro.

(3) Bus stop density

The number of bus stops within 1000m of the station area, import bus stop POI data, establish a 1km buffer zone around the subway station, and find the number of bus stops in the station area, as shown in Figure 3.

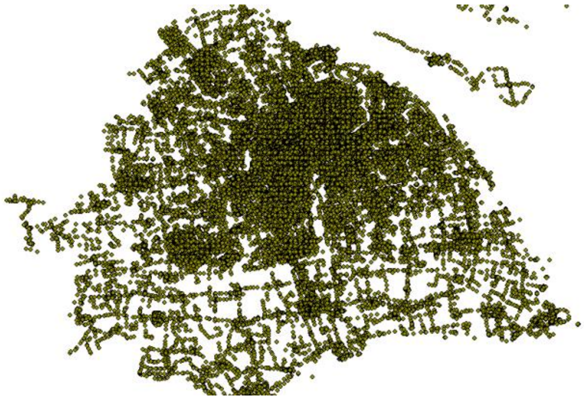

Fig. 3 POI data of bus stations

(4) Parking lot density

The number of parking lots within 1000m of the station area, import the parking lot POI data, establish a 1km buffer zone around the subway station, and find the number of parking lots in the station area, as shown in Figure 4.

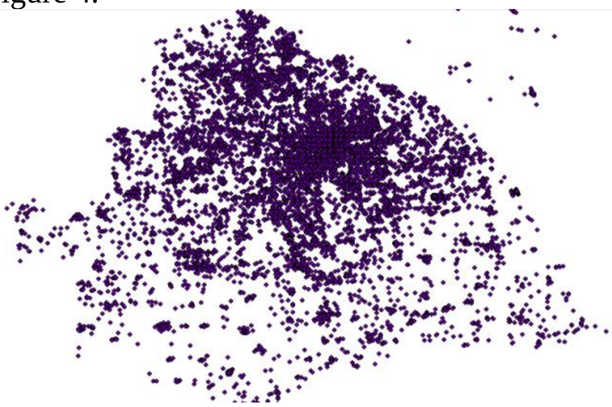

Fig. 4 POI data of parking lot

(5) Average Daily Passenger Volume

The average daily passenger volume of each station along Line 2, the data of this paper is published by Shanghai Traffic Command Center.

4.1.2 Economic efficiency indicators

(1) Unit area housing price

Unit area house price of neighborhoods within 1.5 km of metro stations, data from Dr. Rabbit app.

(2) Commercial service coverage rate

The ratio of the area of commercial service area within 1000m of the station area to the total area of the station area is obtained by establishing a buffer zone and finding the area of commercial service land within the buffer zone, as shown in Figure 6.

(3) Commercial office coverage rate

The ratio of the area of the commercial service area within 1000m of the station area to the total area of the station area is obtained by establishing a buffer zone and finding the area of the commercial office land within the buffer zone, as shown in Figure 6.

4.1.3 Social benefit indicators

(1) Land use diversity

The mixed land use of the surrounding areas within 1000m of the metro station area is calculated by the following formula:

$$\text{Land use diversity } H=-\sum(g \times \ln g), \tag{5}$$

Where, H - land use diversity

g - the ratio of the land area of a certain land use type to the total land area, where each land use type is obtained by establishing a buffer zone within 1000m of the station area, as shown in Figure 6.

(2) Residential area coverage ratio

The ratio of residential land area within 1000m of the metro station to the total area of the station area is obtained by establishing a buffer zone, as shown in Figure 6.

(3) Accessibility of living facilities

Five major categories of medical services, living services, scientific, educational and cultural services, shopping and dining facilities within 1000m of the station area are used as living facilities, and five categories of living facilities POI data are imported to establish a 1km buffer zone around the subway station to find the number of living facilities in the station area, as shown in Figure 5.

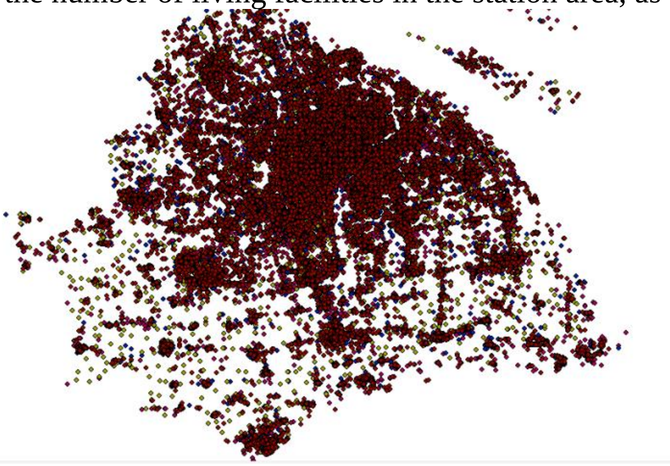

Fig. 5 POI data of living facilities

4.1.4 Environmental benefit indicators

(1) Greening coverage ratio

The ratio of t`he park and green area within 1000m of the station area to the total area of the station area is obtained by establishing a buffer zone and finding the area of park and green land within the buffer zone, as shown in Figure 6.

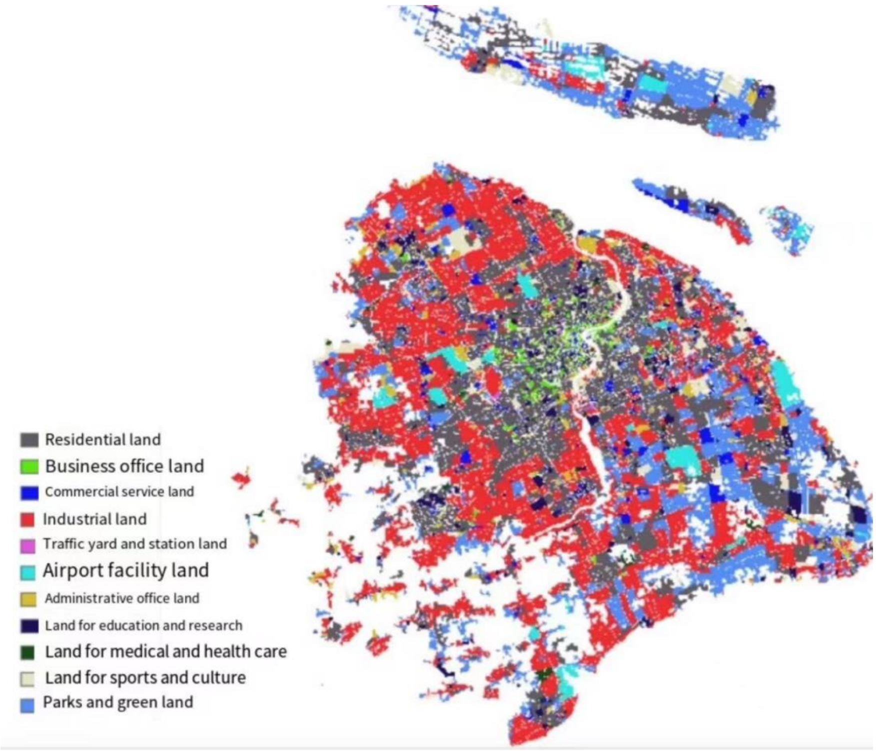

Fig. 6 Shanghai Land Type

(2) Air Quality Index

Based on the data from 19 air quality monitoring stations in Shanghai, the nearest station to the metro station is selected as the air quality data of the metro station area, and the data is obtained from Air Knowing.

4.2. Assignment of weights

4.2.1 Assignment calculation

(1) Construct the judgment matrix and calculate the weights:

The TOD criterion layer judgment matrix is shown in Table 4, and the TOD criterion layer weight vector $\underset{\omega}{\rightarrow} = (0.208{,}0.375.0.375.0.042)$

Table 4 Criterion level judgment matrix

A	Transportation Benefits (A1)	Economic Benefits (A2)	Social Benefits (A3)	Environmental Benefits (A4)	ω	Aω
Transportation Benefits(A1)	1	1/2	1/2	6	0.208	0.837
Economic Benefits(A2)	2	1	1	8	0.375	1.504
Social Benefits(A3)	2	1	1	8	0.375	1.504
Environmental Benefits(A4)	1/6	1/8	1/8	1	0.042	0.171

The scheme layer A1-A1n judgment matrix is shown in Table 5, and the weight vectors $\underset{w}{\rightarrow} = (0.269{,}0.140.0.269.0.052{,}0.269)$

Table 5 Judgment matrix of traffic efficiency index layer

A1	Accessibility(A11)	Subway Frequency (A12)	Bus Station Density (A13)	Parking Lot Density (A14)	Average Daily Passenger Traffic (A15)	ω	Aω
Accessibility(A11)	1	2	1	5	1	0.269	1.348
Subway Frequency(A12)	1/2	1	1/2	3	1/2	0.140	0.700
Bus Station Density(A13)	1	2	1	5	1	0.269	1.348
Parking Lot Density(A14)	1/5	1/3	1/5	1	1/5	0.052	0.260
Average Daily Passenger Traffic(A15)	1	2	1	5	1	0.269	1.348

The scheme layer A2-A2n judgment matrix is shown in Table 6, and the weight vectors $\underset{w}{\rightarrow} = (0.2{,}0.4{,}0.4)$

Table 6 Judgment matrix of economic efficiency index layer

A2	Housing Price Per Unit Area(A21)	Commercial Area Coverage(A22)	Residential Area Coverage(A23)	ω	Aω
Housing Price Per Unit Area(A21)	1	1/2	1/2	0.200	0.600
Commercial Area Coverage(A22)	2	1	1	0.400	1.200
Residential Area Coverage(A23)	2	1	1	0.400	1.200

The scheme layer A3-A3n judgment matrix is shown in Table 7, with the weight vector$\underset{w}{\rightarrow} = (0.333{,}0.528{,}0.140)$

Table 7 Judgment matrix of social benefit indicator layer

A3	Land Use Diversity(A31)	Population Density(A32)	Accessibility of Living Facilities(A33)	ω	Aω
Land Use Diversity(A31)	1	1/2	3	0.333	1.015
Population Density(A32)	2	1	3	0.528	1.612
Accessibility of Living Facilities(A33)	1/3	1/3	1	0.140	0.426

The scheme layer A4-A4n judgment matrix is shown in Table 8, and the weight vectors $\underset{w}{\rightarrow} = (0.500,0.500)$

Table 8 Judgment matrix of environmental benefit index layer

A4	Greenery Coverage(A41)	Air Quality Index(A42)	ω	Aω
Greenery Coverage(A41)	1	1	0.500	1.000
Air Quality Index(A42)	1	1	0.500	1.000

Consistency test of the judgment matrix:

We calculated the TOD criterion layer λ_{max}=4.021, the consistency index CI=(λ_{max}-n)/(n-1)=(4.021-4)/(4-1)=0.0069, the consistency value CR=CI/RI=0.007/0.89=0.0077<0.1, and the consistency of the judgment matrix meets the requirements.

Similarly,

We calculated that λ_{max}=5.004 for scheme layer A1-A1n, consistency indicator CI=0.000997, consistency value CR=0.000891<0.1, the consistency of the judgment matrix satisfies the requirements;

λ_{max}=3 for scheme layer A2-A2n, consistency indicator CI=0, consistency value CR=0<0.1, the consistency of the judgment matrix satisfies the requirements;

λ_{max} =3.054 for scheme layer A3-A3n, consistency indicator CI=0.027, consistency value CR=0.052<0.1, the consistency of the judgment matrix satisfies the requirements;

λ_{max}=2 for scheme layer A4-A4n, consistency indicator CI=0, consistency value CR=0<0.1, the consistency of the judgment matrix satisfies the requirements;

(3) Based on the above results, the integrated weight values are calculated as shown in Table 9:

Table 9 Combined weight values

Site TOD development		
Transportation Benefits A1	Accessibility (A11)	0.056
	Subway Frequency(A12)	0.029
	Bus Station Density(A13)	0.056
	Parking Lot Density(A14)	0.011
	Average Daily Passenger Traffic(A15)	0.056
Economic Benefits A2	Housing Price Per Unit Area (A21)	0.075
	Commercial Area Coverage(A22)	0.150
	Residential Area Coverage(A23)	0.150
Social Benefits A3	Land Use Diversity(A31)	0.125
	Population Density(A32)	0.198
	Accessibility of Living Facilities(A33)	0.052
Environmental Benefits A4	Greenery Coverage(A41)	0.021
	Air Quality Index(A42)	0.021

4.2.2. Descriptive statistics

After quantifying and analyzing the indicators, the results of statistical analysis of indicators for each station along Line 2 are obtained in Table 10.

Table 10 Statistical analysis of indicators

	Maximum	Minimum	Mean Standard	Deviation
Accessibility	4.0	1.0	1.8	1.0
Subway Frequency	15.0	7.5	12.0	3.7
Bus Station Density	850.0	6.0	315.2	267.0
Parking Lot Density	84.0	1.0	32.9	22.5
Average Daily Passenger Traffic	147000.0	1418.0	48159.3	38645.4
Housing Price Per Unit Area	163782.0	25000.0	92426.4	34638.0
Commercial Area Coverage	516000.0	0.0	83066.7	130274.3
Residential Area Coverage	953600.0	0.0	205740.0	234944.5
Land Use Diversity	1.7	0.3	0.8	0.3
Population Density	1707300.0	0.0	592056.7	508167.9
Accessibility of Living Facilities	2468.0	4.0	883.4	771.1
Greenery Coverage	683600.0	0.0	101103.3	174188.9
Air Quality Index	34.0	14.0	24.5	6.7

4.3. Evaluation results

The evaluation results of each station are shown in Table 11, which are obtained by multiplying the weights of each evaluation index obtained from hierarchical analysis with the corresponding quantitative values of Line 2 stations.

Table 11 Comparison of evaluation results of each station

Serial number	Site Name	Evaluation results	Serial number	Site Name	Evaluation results
1	East Nanjing Road	0.500	16	Shanghai Science and Technology Museum	0.333
2	Jing'an Temple	0.486	17	Zhongshan Park	0.330
3	West Nanjing Road	0.456	18	Hongqiao Railway Station	0.321
4	Loushanguan Road	0.447	19	Century Avenue	0.308
5	Longyang Road	0.428	20	Songhong Road	0.299
6	Jiangsu Road	0.420	21	Tangzhen	0.273
7	People's Square	0.410	22	Century Park	0.259
8	Zhangjiang Hi-Tech	0.404	23	Xu Jing Dong	0.248
9	Weining Road	0.378	24	East Huaxia Road	0.237
10	Kawartha	0.377	25	Innovation Middle Road	0.212
11	Jinke Road	0.368	26	Lingkong Road	0.210
12	Beixinjing	0.368	27	Far Eastern Avenue	0.205
13	Dongchang Road	0.350	28	Hongqiao Terminal 2	0.170
14	Lujiazui	0.346	29	Pudong International Airport	0.061
15	Guanglan Road	0.340	30	Haitian Three Road	0.049

5. Conclusions and Recommendations

5.1. Conclusion

The results of the descriptive analysis and the final scores of the sites show that:

① The average daily passenger volume varies widely among different TOD stations, which may be related to the convenience of station interchange and the degree of land use of the station, and the stations with more transportation facilities such as bus stations will reach a larger value, while the passenger volume of rail stations that are in the periphery of the city and have a small amount of accessibility is low, but it should be noted that the passenger volume is not the more the better, but also the capacity of the station should be considered, and for For stations with high passenger volume, we can consider increasing interchange lines to reduce congestion in the station.

② Comparing the unit area housing price in the district where the station is located can be found, located in the prosperous district, such as Jing'an District, Huangpu District, Pudong New Area, People's Square, Jing'an Temple, Lujiazui station area is very high, which is very related to the level of economic development of the TOD site, in urban planning, can consider the expansion of land use of the outer ring road to reduce the pressure of residents to buy houses.

③ The standard deviation of the indicators of accessibility of living facilities and coverage rate of different land types is large, which reflects the concept of TOD development model, emphasizing the development of land in a high-density and high-utilization way, and the diversification of land types near the main living places of residents, and most of the sites around the stations can realize the necessary places for daily life within walking distance, which reflects the good existence of TOD development effect of rail stations.

④ From the analysis of air quality index and greening rate, it is found that there is no greening coverage area around the rail station, which is contrary to the development concept of TOD, and in the future urban planning, emphasis should be placed on designing the land use of greening function, while the air quality index values in several station areas adjacent to Pudong airport station are low, but the overall difference is not big, in this aspect, the development of urban center area lags behind the overall higher level of TOD of the stations.

⑤ Comparing the results of the total rating of each station, the stations with better ratings at present are mainly distributed in East Nanjing Road, People's Square, Jing'an Temple Station, etc. These stations are mainly located in Huangpu District, Jing'an District, Pudong New Area and other areas of Shanghai with high prosperity and advanced development, which can verify that the sound development of TOD mode will accelerate the construction of the area, and these core TOD stations can expand to the surrounding areas and drive other areas The construction of comprehensive level.

5.2. Recommendations

① Improving the accessibility of TOD stations

Based on the Node-Place model and the 5D principle, we can obtain the layout of land development and utilization within the TOD station area and the convenience of traffic interchange, and then believe that the improvement of station area accessibility can consolidate the traffic carrying capacity, and can ease the travel pressure by increasing the number of bus stations within the TOD station area, appropriately increasing the number of rail lines and the number of station entrances and exits, so as to promote the diversified urban development, gradually expand the economic, environmental and social benefits of the station area, and thus promote urban upgrading.

② Integrated development of urban planning and transportation planning

TOD model is a synergistic development concept of rail transit stations and urban land use. TOD-oriented urban development can not only reshape the image of cities and develop urban land rationally, but also promote urban growth and improve urban energy and level. When considering urban construction, we cannot prioritize urban planning and design transportation separately afterwards. Urban rail transit development should promote mixed land use in the station area, targeted layout planning and updating according to the scoring of stations, and form an integrated development model of urban construction and rail transit integration.

③ Policy to guide public transportation travel

Urban rail transit is the direction of modern urban transportation development, and rail transit travel can effectively solve the big city disease. In order to better promote TOD strategic planning, the government should ensure the implementation of various policies and regulations, clarify the division of responsibilities of each main body of public transportation construction, implement institutional reform, reasonably promote market competition, and create a "TOD-led urban development concept ".

④ Build a green travel environment

Coordinate the construction of non-motorized travel environment around TOD stations, increase non-motorized lanes, parking facilities, pedestrian rest areas, travel and entertainment areas, etc., to create a "people-oriented" travel mode, which will promote the frequency of passengers using non-motorized vehicles and public transportation to effectively transfer to their destinations, reduce fuel consumption and exhaust emissions, and build a sustainable city. Sustainable Cities.

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