International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-2; Mar-Apr, 2024
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Evaluation of Land Use and Road System for Urban Planning in Luohu District, Shenzhen, Based on GIS

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Received: 15 Jan 2024; Received in revised form: 22 Feb 2024; Accepted: 28 Feb 2024; Available online: 08 Mar 2024

Abstract*— This study aims to evaluate the urban planning system of land use and road system in Luohu, Shenzhen. Based on remote sensing images, 30 m DEM data, population data, and various urban planning standards, the land use types in the Luohu built-up area are determined through comprehensive analysis and evaluation: a road system that covers the slope, area, area ratio, and intersection spacing of road longitudinal sections, as well as a bus system that covers the density of the bus network, non-linear coefficient, network length, average station spacing, repetition coefficient, and station coverage. The study results show that the overall urban planning of Shenzhen Luohu is incomplete, and the land use, road system, and bus routes in the built-up area are not reasonable enough. Finally, suggestions are proposed to address the shortcomings, such as revitalizing existing land resources and promoting the efficient and intensive use of industrial land.*

Keywords**— Geographic Information System (GIS), Land use; Road system, Bus routes, City planning**

I.INTRODUCTION

Urban planning is the blueprint for urban development and construction, as well as the basic basis for urban construction and management. It has a huge, complex, and long-term impact on urban development and the ecological environment of surrounding areas. Therefore, evaluating urban planning can promote the implementation of urban sustainable development strategies (Mo, 2006). Generally speaking, study on urban planning systems can be evaluated from three aspects: land use, road network systems, and public transportation routes. Among them, land use planning is an indispensable link in urban development, referring to the process of rational allocation of land resources within the city, and is a concept that is carried out to meet the needs of sustainable urban development (Cheng, 2024). Based on the current socio-economic and natural conditions as well as the requirements of national economic development coordinate the total supply and demand of land and arrange the total amount of land use. It has the characteristics of protecting and regulating land use, so it is also known as the "gate" of urban development (Hu, 2010).

In addition, the planning of the road network system is the main foundation of urban transportation construction. Assuming that land use is likened to the body of the city, the road network system is like the blood of the body, responsible for the transportation of blood and nutrients to the city. Whether its planning is scientific and reasonable directly affects various conditions of urban development, including whether it can adapt to social and economic development and whether various modes of transportation can coordinate and closely cooperate with each other. Whether the road network system produces the best socio-economic benefits and whether the transportation of people and things is convenient, fast, comfortable, economical, and safe (Chen, 2009), Among them, urban public transportation is an indispensable element of urban travel, an artery to ensure the normal operation of urban production and life, and an important infrastructure to improve the comprehensive function of the city. It plays an important role in the development of various industries in the city, the prosperity of the economy and cultural undertakings, and the connection between urban and rural areas (Ma, 2003; Meng, 2020).

Based on this, this study adopts GIS technology as the foundation and evaluates land use, road network systems, and public transportation roads through method analysis and standard indicator evaluation, attempting to interpret whether the various standards in the study area comply with modern urban planning indicators and propose relevant suggestions.

II. STUDY AREA AND DATA SOURCES

2.1 Study Area

Luohu District is located in the south-central part of Shenzhen City and the central part of the Shenzhen Special Economic Zone. Its geographical coordinates are 114 ° 06′ -114 ° 22′ E and 22 ° 53′ -22 ° 62′ N. It is bounded by the Wutong Mountain Bogong Ao watershed and Yantian District in the east, connected to Futian District by the middle line of Hongling Road in the west, and bordered by Longgang District and Longhua District in the north (Figure 1). The total area of the jurisdiction is 78.79 square kilometers, including 36.02 square kilometers of built-up areas.

According to the 2022 National Economic and Social Development Statistics Bulletin, the urban green coverage area of Luohu District is 5176.74 hectares, with a green coverage rate of 64.6%. The area of garden green space is 4987.3 hectares, of which the area of park green space is 1712.1 hectares. There are 111 parks, including 15 municipal parks and 96 community parks. As of 2022, the permanent population of Luohu District is 1.018 million. The built-up areas in Luohu District are concentrated in the central and southeastern parts, with mostly mountainous areas on the east and west sides, scattered in the built-up areas, and a large area of water in the northeast. To serve the transportation of people in the area, there are 11 main roads in both horizontal and vertical directions, with a total length of 208.42 kilometers. There are currently 183 bus routes, 15.27 hectares of bus stops, and more than 600 bus stops.

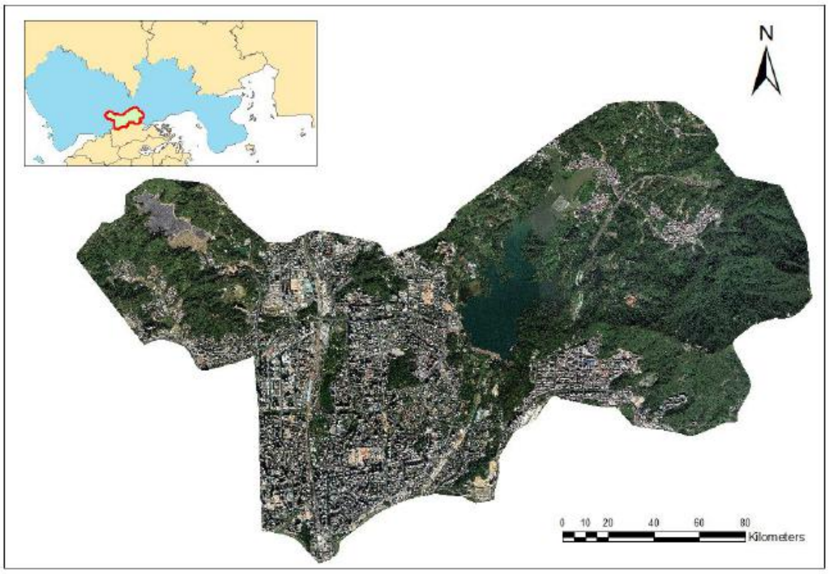

Fig.1 Map of the Study Area

2.2 Data Sources

This study mainly used three types of data: vector boundary range data in Luohu District, image data, and 30m DEM elevation data (Table 1).

Table 1 Data Sources

Data type	Data sources	Data usage
Vector boundary range data	Resource and Environmental Science and Data Center（https://www.resdc.cn/）	Used to delineate the scope of the research area
Image data	LocaSpace Vewer（http://www.locaspace.cn/）	Used for vectorizing urban functional areas
Demographic data	Shenzhen Luohu District People's Government http://www.szlh.gov.cn/wxlh/zjlh/lhsj/）	Used to calculate per capita urban construction land and per capita individual construction land
30mDEM	Geospatial data cloud (https://www.gscloud.cn/）	Used to calculate the slope of road profiles
Code for Urban Road Traffic Planning and Design (GB 50220-95)	Ministry of Housing and Urban Rural Development of the People's Republic of China（https://www.mohurd.gov.cn/）	Used to evaluate the density, non-linear coefficient, repetition coefficient, length, average station distance, and station coverage of urban road longitudinal section slope, road area, and bus route network
Classification of Urban Land and Standards for Planning and Construction Land (GB 50137-2011)		Used to evaluate per capita urban construction land, per capita individual construction land, construction land structure, and classification of urban construction land built-up areas
Design Specification for Urban Road		Used to evaluate the spacing between road

Intersections (CJJ 152-2010)		intersections
Design Code for Urban Road Traffic Facilities (GB 50688-2011)		
Design Specification for Urban Road Engineering (CJJ37-2012)	Ministry of Housing and Urban Rural Development of the People's Republic of China(http://swj.sz.gov.cn/attachment/1/1151/1151906/2945061.pdf）	Used for graded urban roads
Shenzhen Urban Planning Standards and Guidelines	Shenzhen Planning and Natural Resources Bureau(https://www.sz.gov.cn/attachment/1/1133/1133902/10013132.pdf）	Write a land balance sheet

III. METHODOLOGY

3.1 Study Schema

In order to evaluate the urban planning of Luohu District, this study starts with the land use, road system, and public transportation roads in the built-up area. Firstly, the registered image maps are vectorized to obtain the urban transportation roads, urban functional area division, and public transportation routes and stations. Based on the processed transportation road network, the longitudinal slope, area, and area ratio of the road, as well as the spacing between intersections, are obtained. Based on bus routes and stations, the density of bus routes is obtained using fishing net tools. The non-linear coefficient, network length, and average station distance of bus routes are obtained using distance measurement tools. The bus repetition coefficient is obtained through buffer zone analysis. The 800 m bus service area is obtained through network analysis, and the coverage rate of bus stations is obtained (Figure 2).

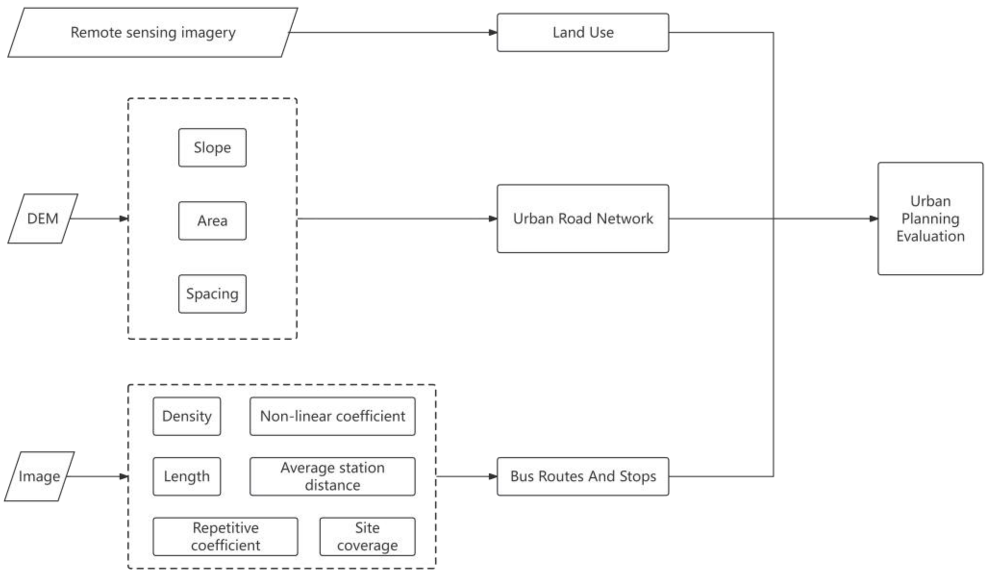

Fig.2 The Flowchart of the Study Schema

3.2 Land Use in Built-up Areas

3.2.1 Evaluation Criteria for Per Capita Urban Construction Land

According to the Classification and Planning of Urban Land and the Standard for Construction Land (GB 50137-2011), per capita urban construction land refers to the area of urban construction land within a city divided by the number of permanent residents within that area, with a unit of m2/person. The evaluation standard is that the per capita urban construction land index for planning should be determined comprehensively based on the current per capita urban construction land index, the climate zone where the city is located, and the planned population size, using Table 2 as the standard. Meanwhile, it should comply with the limit requirements of the allowed per capita urban construction land index and the allowed adjustment range in the table.

Table 2 Planning per capita urban construction land indicators（m^2/ person）

Climate zone	Current per capita urban construction land indicators	Permissible per capita urban construction land indicators for planning	Allow adjustment range		
			Planned population size ≤200 thousand people	Planned population size 201 ～ 500 thousand people	Planned population size ＞500 thousand people
I、II、VI、VII	≤65.0	65.0～85.0	＞0.0	＞0.0	＞0.0
	65.1～75.0	65.0～95.0	+0.1～+20.0	+0.1～+20.0	+0.1～+20.0
	75.1～85.0	75.0～105.0	+0.1～+20.0	+0.1～+20.0	+0.1～+15.0
	85.1～95.0	80.0～110.0	+0.1～+20.0	-5.0～+20.0	-5.0～+15.0
	95.1～105.0	90.0～110.0	-5.0～+15.0	-10.0～+15.0	-10.0～+10.0
	105.1～115.0	95.0～115.0	-10.0～-0.1	-15.0～-0.1	-20.0～-0.1
	＞115.0	≤115.0	＜0.0	＜0.0	＜0.0
III IV V	≤65.0	65.0～85.0	＞0.0	＞0.0	＞0.0
	65.1～75.0	65.0～95.0	+0.1～+20.0	+0.1～20.0	+0.1～+20.0
	75.1～85.0	75.0～100.0	-5.0～+20.0	-5.0～+20.0	-5.0～+15.0
	85.1～95.0	80.0～105.0	-10.0～+15.0	-10.0～+15.0	-10.0～+10.0
	95.1～105.0	85.0～105.0	-15.0～+10.0	-15.0～+10.0	-15.0～+5.0
	105.1～115.0	90.0～110.0	-20.0～-0.1	-20.0～-0.1	-25.0～-5.0
	＞115.0	≤110.0	＜0.0	＜0.0	＜0.0

Based on the analysis of current land use statistics and the principles of conservation and intensive land use, this standard sets the upper and lower limits of per capita urban construction land indicators for urban planning located in climate zones I, II, VI, and VII at 65.0~115.0 m^2/person and the upper and lower limits of per capita urban construction land indicators for urban planning located in climate zones III, IV, and V at 65.0~110.0 m^2/person.

The per capita urban construction land quota for newly built cities should be determined within 85.1~105.0 m^2/person. The per capita urban construction land quota for the capital should be determined within the range of 105.1 to 115.0 m^2/person. When remote areas, cities in ethnic minority areas, as well as some mountainous cities, industrial and mining cities with small populations, scenic tourism cities, etc., if do not meet the requirements, a special demonstration should be conducted to determine the planned per capita urban construction land index, and the upper limit should not exceed 150.0 m^2/person.

3.2.2 Evaluation Criteria for Per Capita Individual Construction Land

Per capita single construction land refers to the area of residential land, public management and service land, road and transportation facility land, as well as green space and square land within the city, divided by the number of permanent residents within the urban construction land range, in m^2/person. According to the "Classification of Urban Land and Standards for Planning and Construction Land" (GB 50137-2011), the per capita residential land indicators for planning should comply with the provisions of Table 3.

Table 3 Indicators of Per Capita Residential Land Area（m^2 / person）

Climatological zoning for buildings	I、II、VI、VII Climate zone	III、IV 、V Climate zone
Per capita residential land area	28.0 ~ 38.0	23.0 ~ 36.0

The planned per capita area of public management and public service land should not be less than 5.5 m^2/person. The planned per capita land area for roads and transportation facilities should not be less than 12.0 m^2/person. Then, the planned per capita green space and square land area should not be less than 10.0 m^2/person, among which the per capita park green space area should not be less than 8.0 m^2/person.

3.2.3 Evaluation Criteria for Construction Land Structure

The structure of construction land refers to the proportion obtained by dividing the area of residential land, public management and service land, industrial land, road and transportation facilities land, as well as green space and square land within a city by the area of urban construction land (%). According to the Urban Land Classification and Planning Construction Land Standard (GB 50137-2011), the proportion of residential land, public management and public service land, industrial land, road and transportation facility land, and green space and square land in urban construction land planning should comply with the provisions of Table 4.

The planned urban construction land structure of industrial and mining cities, scenic tourism cities, and other cities with special circumstances can be determined based on the actual situation.

Table 4 Planning Urban Construction Land Structure

Land use name	Proportion of urban construction land（%）
Residential land	25.0 ~ 40.0
Public management and public service land	5.0 ~ 8.0
Industrial land	15.0 ~ 30.0
Road, street and transportation	10.0 ~ 25.0
Green space and square land	10.0 ~ 15.0

3.2.4 Land Balance Sheet

The urban land balance sheet is a planning tool for urban development, used to display and plan the area and proportion of various types of land within the city. It provides a detailed list of eight types of land, including public management and public service land, logistics and warehousing land, industrial land, green space and square land, commercial service facility land, residential land, road and transportation facility land, and urban construction land. It also provides the land area, proportion of urban construction land, per capita urban construction land status, and planned area for each type of land. The land use balance sheet plays an important role in urban planning, resource allocation, sustainable development, policy formulation, and public participation. It is an important tool for urban planning and management, which helps to achieve rational development and an optimized layout of the city.

3.3 Road System Evaluation Methods

3.3.1 Road Longitudinal Section Slope

The longitudinal slope of urban roads refers to the ratio of the height difference between two points on the same slope section of a route and its horizontal distance, expressed as a percentage. The maximum longitudinal slope is the maximum value of the longitudinal slope determined by factors such as road grade, natural conditions, driving requirements, and street-facing buildings. The minimum longitudinal slope is the minimum longitudinal slope specified for sections with poor drainage for longitudinal drainage needs.

In practical situations, the slope of a road is generally expressed in two ways: percentage display or the degree method. The percentage method is the most commonly used method for measuring slope, which is the percentage

$$S = \frac{(h-l)}{100}$$

of the elevation difference between two points and their total length. Its calculation formula is as follows:

In the formula, S is the longitudinal slope of the road, h is the elevation difference of the road, and l is the total length of the road

3.3.2 Road Area

The urban road area refers to the length of the road multiplied by the width of the road. According to the "Shenzhen Urban Planning Standards and Guidelines" issued by the Shenzhen Municipal Planning and Natural Resources Bureau, the control of road width is shown in Table 5:

Table 5 Corresponding widths of roads of different levels

Road class	Total Road Width
Expressway	35 - 80
Main road	30 - 50
Secondary trunk road	26 - 35
by-pass	16 - 25

The urban road area ratio, also known as the "urban road area density," is expressed as the percentage of the area of roads (roads refer to roads with a width of 3.5 meters or more paved, excluding sidewalks) within the urban built-up area. The urban road area ratio is an important economic and technical indicator that reflects the ownership of urban roads in urban built-up areas.

3.3.3 Road Intersection Spacing

Road intersection spacing refers to the distance between the centers points of two adjacent road intersections. From a transportation perspective, in general, there is an intersection every 200 meters, which may feel too dense and conflicted, making it inconvenient for vehicle driving and traffic management. However, there is only one intersection between 800-1000m, which is not convenient for the entry and exit of residential areas and neighborhoods. Therefore, in order to facilitate the walking and driving of pedestrians and vehicles, the distance between road intersections should be 300–800 m. Different levels of roads have different functions and design speeds, resulting in varying distances between corresponding road intersections. The spacing between intersections of urban expressways, main roads, secondary roads, and branch roads should be 1500–250 m, 700–1200 m, 350–500 m, and 150–250 m, respectively (Shi, 2007).

3.4 Public Transport Network

The public transportation network is composed of fixed stations arranged for urban public transportation based on urban streets. This study will use the evaluation index system summarized by Li et al. (2003) to evaluate the public transportation network in Luohu District, including road network density, road network length, non-linear coefficient, repetition coefficient, average station distance, and station coverage.

3.4.1 Road Network Density

Road network density refers to the ratio of the total length of the road centerline of the bus route to the area of the bus service city. It is used to reflect the relative size and average distribution of the bus network and can also reflect the degree to which residents are close to the bus route. The formula is as follows:

$$\delta = \frac{L_0}{F}$$

In the formula, δ refers to the density of the public transportation network, L0 refers to the total length of the road centerline of the bus route, and F refers to the area of the bus service city, unit in km/ km^2.

According to the Code for Urban Road Traffic Planning and Design (GB 50220-95), the density of the public transportation network planned in the city center should reach δ = 3–4 km/ km^2. In urban fringe areas, it is necessary to achieve δ = 2–2.5 km/ km^2. According to theoretical analysis, the average density of the urban public transportation network is δ = 2.5 km/ km^2 (Kuang, 2005).

The density of a city's public transportation network must be appropriate. It is generally believed that the higher the density of the public transportation network, the more convenient the transportation connections will be. However, if the density is too high, it can cause problems such as inefficient urban land use, severe barriers between urban areas, increased investment in urban road construction, and the formation of too many intersections, affecting the speed of vehicle travel and the capacity of main roads. A low density can cause traffic vehicles to detour, increase travel time, and fail to fully utilize the distribution function of the public transportation system, leading to traffic congestion (Li, 2008).

3.4.2 Road Network Length

$$l_{\min} \le l \le l_{\max}$$

In the formula, lmin is the upper limit of the route length (km), and lmax is the lower limit of the route length (km). According to the operating requirements of the "Urban Road Traffic Planning and Design Specification (GB 50220-95)" issued by the National Bureau of Technical Supervision, the lmin is about 5km and the lmax is about 15km (Liu, 2008).

3.4.3 Non Linearity Coefficient

$$[\frac{l_k}{d_k}] \le [\frac{l}{d}]_{\max}$$

In the formula, l_k is the length of line k (km), and d_k is the spatial straight-line distance between the starting and ending stations of the line (km). According to the "Code for Urban Road Traffic Planning and Design (GB50220-95)," the non-linear coefficient of public transportation lines should not exceed 1.4, and the average non-linear coefficient of the entire network is 1.15–1.2, which is suitable for evaluating the convenience of the connection between different road network types and the distribution points of passenger and freight flow routes (Li, 2008).

3.4.4 Repetition Coefficient

The repetitive coefficient refers to the ratio of the total length of the bus operation route to the total length of the bus network. The formula used to reflect the density of bus routes on major urban roads and the degree of repetition of bus routes is as follows:

$$\mu = \frac{L}{L_0}$$

In the formula, μ refers to the repetition coefficient of the public transportation network, L refers to the total length of bus operation routes, L0 refers to the total length of the bus network, and the ratio has no units. According to the Code for Urban Road Traffic Planning and Design (GB50220-95), the repetition coefficient μ, the upper limit is 3.1, and the lower limit is 1.2. It is generally believed that μ = 1.2–1.5 is a reasonable value (Kuang, 2005).

3.4.5 Average Stop Spacing

The calculation of average station distance is based on the average distance between the bus stop and its nearest bus stop, calculated using the "distance matrix" tool of QGIS software. According to the "Code for Urban Road Traffic Planning and Design (GB 50220-95), the average station distance in the urban area should not exceed 400m, and the average station distance in the suburbs should not exceed 800m.

3.4.6 Bus Stop Coverage

Station coverage is the percentage of the service area of bus stops in the urban land area. It refers to the ratio of the total number of stops N on the bus route to the service area during the statistical period. It is used to represent the average distribution of bus stops within the bus service area. The coverage rate of bus stops reflects the degree to which residents are close to bus stops. It is one of the important indicators used to measure whether it is convenient for citizens to use buses. It can be expressed as follows (Wang, 2008):

Bus stop coverage = number of bus stops x service area of bus stops / land area of urban zoning

According to the "Code for Urban Road Traffic Planning and Design (GB 50220-95), the service radius of urban bus stops is divided into three ranges: 300m, 500m, and 800m. The service area of public transportation stations is calculated based on the 500-meter service radius and shall not be less than 90%. The 300m and 500m radius service areas are more meaningful for the study of conventional ground bus systems, and the 800m radiation radius is more suitable for the analysis of backbone public transportation with large operating volumes, such as subways. Therefore, this study takes the 500-meter-radius service area as the main evaluation indicator (Li, 2015). However, according to the above calculation formula, the sum of areas is not the algebraic sum of all areas covered by the region, but the area after geometric merging of the regions, that is, the result of subtracting the overlapping area from the algebraic sum of areas.

IV. ANALYSIS AND RESULTS

4.1 Analysis of Land Use in Built-up Areas

The analysis of functional zones for urban construction land is based on Figure 3. Among them, the functional areas of urban construction land are classified according to the "Classification and Planning of Urban Land and Construction Land Standards (GB50137-2011)". In addition to public facility land, they are divided into seven types of land: residential land, commercial service facility land, public management service facility land, industrial land, logistics and warehousing land, road and transportation land, green space, and square land. In addition, water areas are also divided. Among them, the area and total area data of each functional area of urban construction land are shown in Table 6:

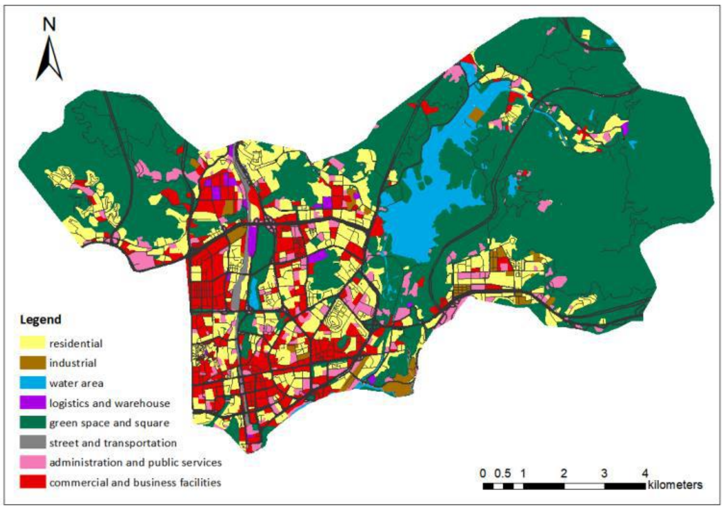

Fig.3 Classification of Functional Areas for Urban Construction Land

Table 6: Area and Total Area of Each Functional Area of Urban Construction Land

Functional Area	Unit（km2）
Public management and public service land	4.28
Logistics and warehousing land	0.55
Industrial land	1.20
Green space and square land	43.91
Land for commercial service facilities	7.29
Residential land	13.15
Roads and transportation land	0.46
total area	71.32

4.1.1 Analyze Per Capita Urban Construction Land

Based on the per capita urban construction land standard, Luohu District in Shenzhen belongs to the Class IV climate zone, with a per capita urban construction land area range of 65.0 to 110.0 square meters (Table 7).

Table 7 Per Capita Urban Construction Land Standards

Climatological zoning for buildings	I、II、VI、VII Climate zone	III、IV 、V Climate zone
Per capita urban construction land area	65.0 ~ 115.0	65.0 ~ 110.0

According to the data vectorized by ArcGIS software, the total area of urban construction land in Luohu District, Shenzhen, is 70.06 km2. The permanent population is 1.018 million, and the per capita urban construction land area in Luohu District is calculated by dividing the total urban construction land area by the local permanent population. The per capita urban construction land area in Luohu District is 70.06 square meters per person. Meet the standard range of 65.0 to 110.0 square meters (Table 8).

Table 8 Per Capita Urban Construction Land Area in Luohu District

Total area （km²）	Permanent population （ ten thousand people）	Per capita urban construction land area （㎡/ people）
71.32	101.8	70.06

4.1.2 Analyze Per Capita Individual Construction Land

Based on the per capita construction land standard, Luohu District in Shenzhen belongs to the Class IV climate zone, with an average residential land area of 23.0–36.0 square meters per person. The per capita area of public management and public service land in the plan should not be less than 5.5 ㎡/person. The planned per capita land area for roads and transportation facilities should not be less than 12.0 ㎡/person. The planned per capita green space and square land area should not be less than 10.0 ㎡/person, among which the per capita park green space area should be greater than 8.0 ㎡/person (Table 9).

Table 9 Per Capita Single Construction Land Standards

Climatological zoning for buildings	I、II、VI、VII Climate zone	III 、 IV 、 V Climate zone
Per capita residential land area	28.0 ~ 38.0	23.0 ~ 36.0

The public management and public service land in Luohu District is 4.3 ㎡/person, which is lower than the national standard of 5.5 ㎡/person and does not meet the requirements of the national standard. The land for green spaces and squares is 43 ㎡/person, which is higher than the national minimum standard of 10.0 ㎡/person and meets the national standard requirements. The road and transportation land area is 0.5 ㎡/person, which is significantly lower than the national standard of 12.0 ㎡/person and does not meet the requirements. The residential land area is 13 ㎡/person, which is lower than the national standard of 23.0 ㎡/person and does not meet the requirements (Table 10).

Table 10: Per Capita Area of Various Construction Land in Luohu District

Functional Area	Unit (km^2)	Per capita area (㎡/ person)
Public management and public service land	4.36	4.28
Logistics and warehousing land	0.56	0.55
Industrial land	1.23	1.20
Green space and square land	43.91	43.91
Land for commercial service facilities	7.42	7.29
Residential land	13.38	13.15
Roads and transportation land	0.46	0.46

4.1.3 Analyze the Structure of Construction Land

Based on the construction land structure standards and the analysis of the proportion of various land uses in Luohu District, it is found that the proportion of residential land is 19%, which does not meet the range of 25.0–40.0% in the national standard. The proportion of public management and public service land is 6%, which meets the national standard of 5.0–8.0%. The proportion of industrial land is 2%, which does not meet the national standard range of 15–30%. The land for roads and transportation facilities is 1%, which does not meet the national standard range of 10.0–25.0%. The proportion of green space and square land is 62%, exceeding the appropriate range of national standards of 10.0–15.0 (Table 11).

Table 11 Proportion of Land Use in Luohu District

Functional Area	The proportion of construction land structure standards（%）	The proportion of various land uses（%）
Public management and public service land	5.0 ~ 8.0	6%
Logistics and warehousing land		1%
Industrial land	15.0 ~ 30.0	2%
Green space and square land	10.0 ~ 15.0	62%
Land for commercial service facilities		10%
Residential land	25.0 ~ 40.0	19%
Roads and transportation land	10.0 ~ 25.0	1%

4.1.4 Land Balance Sheet

Based on the planning and requirements for various types of land in the Shenzhen Urban Planning Standards and Guidelines and combined with actual situations, the land area, proportion of urban construction land, and per capita urban construction land status and planning for eight types of land are obtained. Among them, the area of land for public management and public services, industrial land, residential land, roads, and transportation facilities is planned to expand, while the area of land for logistics and warehousing, commercial service facilities, and urban construction remains the same. The area of land for green spaces and squares is planned to decrease (Table 12).

Table 12 Land Balance Table of Luohu District, Shenzhen

Land use code	Land use name	Land area（km2）		Proportion of urban construction land（%）		Per capita urban construction land（km2/person）	
		Present situation	Plan	Present situation	Plan	Present situation	Plan
A	Public management and public service land	4.36	5.59	6	8	4.28	5.5
W	Logistics and warehousing land	0.56	0.56	1	1	0.55	0.55
M	Industrial land	1.23	10.70	2	15	1.20	10.51
G	Green space and square land	43.91	11.43	62	16	43.13	11.22
B	Land for commercial service facilities	7.42	7.42	10	10	7.29	7.29
R	Residential land	13.38	23.41	19	33	13.15	23
S	Roads and transportation land	0.46	12.21	1	17	0.46	12
H	Urban construction land	71.32	71.32	100	100	70.06	70.06

4.2 Urban Road Analysis

According to the road classification standards of the "Design Specification for Urban Road Engineering (CJJ37-2012)" standard, the road classification map of Luohu District in Shenzhen (Figure 4) and the road classification map at all levels of Luohu District in Shenzhen (Figure 5) are classified. Expressways can be roughly divided into "four vertical and two horizontal," with the main road mainly concentrated in the urban center and extending to the eastern and western mountainous areas, and the branch road connecting the traffic of the urban center and the eastern and western mountainous areas. The secondary road connects urban buildings and residential buildings.

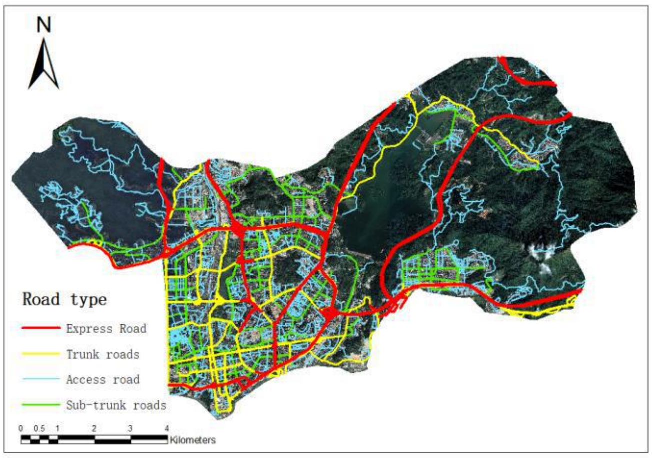

Fig.4 Road Classification Map of Luohu District, Shenzhen

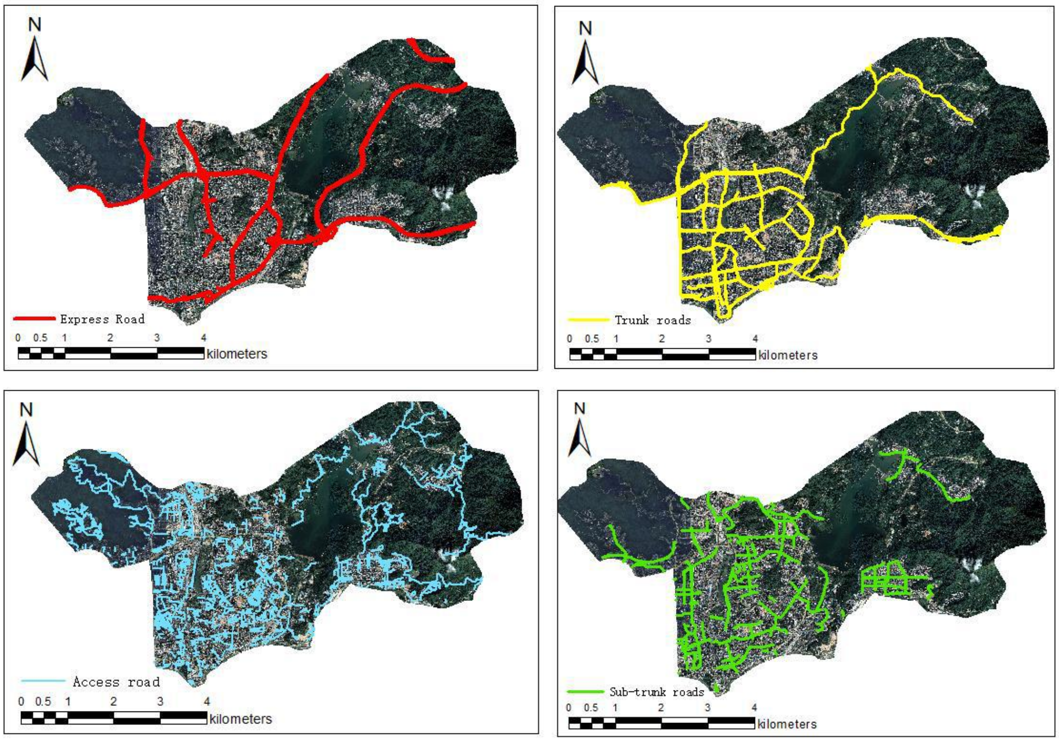

Fig.5 Classification map of various roads in Luohu District, Shenzhen

4.2.1 Analysis of Vertical Section Slope of Urban Main Roads

According to the distribution of main roads obtained from Figures 4 and 5, as well as the limit values formulated based on vehicle power characteristics and considering economic factors, they should not be easily adopted in the design, leaving room for error. Generally speaking, it is better to have a gentle longitudinal slope, but for the drainage of the road surface and side ditches, the minimum longitudinal slope should not be less than 0.3% to 0.5% (Table 13) (Liu, 2011).

Table 13 Main Technical Indicators of Chinese Highways

Highway grade	Expressway		一		二		三		四	
terrain	Plain hills	Mountains and heavy hills	Plain hills	Mountains and heavy hills	Plain hills	Mountains and heavy hills	Plain hills	Mountains and heavy hills	Plain hills	Mountains and heavy hills
Calculate driving speed (km/h)	120	80	100	60	80	40	60	30	40	20
Maximum longitudinal slope (%)	3	5	4	6	5	7	6	8	6	9

Usually, the design of longitudinal section alignment follows the following principles (Ma, 2009):

1) The vertical section design should refer to urban road planning to control the elevation and adapt to the layout of

building facades along the street and the drainage of surface water along the road range;

2) To ensure safe and comfortable driving, the longitudinal slope should be gentle and smooth, and the undulations should not be frequent.

3) The design of longitudinal sections of mountain roads and newly opened roads should take into account the balance of earthwork and the economic effects of automobiles. Reasonably arrange the road surface design elevation;

4) The lane where motor vehicles and non-motor vehicles are mixed should be designed with a longitudinal slope based on the climbing ability of non-motor vehicles;

5) The longitudinal section design should comprehensively address the requirements of terrain, underground pipelines, geology, hydrology, climate, and drainage.

By analyzing the longitudinal slope of the main road in Luohu District, it is found that all of them meet the technical indicators of Chinese highways and the roads are smooth (Table 13).

Table 13 Longitudinal Section Slope of Main Roads in Luohu District

Road name	Road length（m）	Profile grade（%）	Whether it complies with national standards（≤5%)
Honghu West Road	1900	0.63%	YES
Ja bin Road 1	3400	1.41%	YES
Honggui Road1	1700	1.06%	YES
Beihuan Avenue 1	2400	1.38%	YES
Riverside Drive 1	1500	1.73%	YES
Heping Road	4400	0.86%	YES
Honggang Road 1	3900	0.90%	YES
Honggang Road 2	4000	1.03%	YES
Honggang Road 1	1800	1.06%	YES
Honggui Road 2	1700	1.06%	YES
Hongling North Road 2	342100	0.05%	YES
Ja bin Road 2	4800	1.44%	YES
Jianshe Road 1	4000	1.85%	YES
Jiaohu Road 1	1800	1.50%	YES
Jiaohu Road 2	1800	1.39%	YES
Nigang East Road 1	3600	0.53%	YES
Nigang East Road 2	7100	0.76%	YES
Qingping Expressway 1	1800	0.89%	YES
Qingping Expressway 2	1600	0.88%	YES
People's Park Road 1	2800	1.25%	YES
People's Park Road 2	2800	1.36%	YES
Drying Cloth Road 1	800	4.13%	YES
Drying Cloth Road 2	800	4.13%	YES
Shennan East Road 1	9500	0.46%	YES

Shennan East Road 2	9000	0.67%	YES
Sungang Road 1	5600	0.66%	YES
Sungang Road 2	5500	0.60%	YES
Xinxiu Road	1800	1.94%	YES
Xinyuan Road	1800	1.78%	YES

4.2.2 Analysis of urban road area

The urban road area ratio, also known as the "urban road area density," is expressed as the percentage of the area of roads within the urban built-up area (roads refer to roads with a paved width of 3.5 meters or more, excluding sidewalks) to the built-up area. The formula is: road area ratio=total area of road land/total area of construction land. The urban road area ratio is an important economic and technical indicator that reflects the ownership of urban roads within the urban built-up area. According to calculations, the built-up area of Luohu District is 71320591 square meters. Therefore, the road area ratio of Luohu District is shown in Table 14:

Table 14 Road Area Ratio in Luohu District

Road category	Length（m）	Road area（㎡）	Urban road area ratio（%）
Expressway	123941.76	4337961.72	6.08
Main road	149252.53	4477575.76	6.28
Secondary trunk road	110780.04	2880280.95	4.04
by-pass	243602.13	3897634.08	5.46

The area ratio of urban roads refers to the proportion of the land area of roads to the urban construction land area. According to the "Code for Urban Road Traffic Planning and Design" (GB50220-95), the land area of urban roads should account for 8–15% of the urban construction land area. For large cities with a planned population of over 2 million, it is recommended to be 15%–20%. The population of Luohu District in 2022 will be 1.018 million people, and the total area ratio of urban roads will be 21.87%, which is consistent with the "Code for Urban Road Traffic Planning and Design." According to the regulations (GB50220-95), the road area in Luohu District is 6.87% higher than the urban construction land area.

Therefore, the proportion of the road area in Luohu District to the urban construction land area is too high. The urban road area ratio is an important economic and technical indicator that reflects the ownership of urban roads in the urban built-up area. A high road area ratio in Luohu District means an increase in road investment. With relatively more roads, traffic congestion will naturally decrease. However, a high road area ratio is not conducive to the construction of the urban environment. A high road area ratio can cause an increase in intersections, potentially leading to traffic congestion. If the road area is too high, the urban green area will decrease. It also means that the already tense residential activity land is further squeezed, which is not conducive to the efficient development of land resources.

4.2.3 Analysis of Road Intersection Spacing

According to the industry standard "Design Regulations for Urban Road Intersections (CJJ 152-2010)" issued by the Ministry of Housing and Urban Rural Development of China, the spacing between level crossings should be determined based on the size of the city, road network planning, road types, and their regional location in the city; the spacing between main road intersections should be roughly equal; the minimum spacing between various types of intersections should meet the minimum length required for turning vehicles to change lanes, the maximum queue length for vehicles during the red light period, and the total length of the entrance and exit lanes, and should not be less than 150m.

According to the national standard "Design Specification for Urban Road Traffic Facilities (GB 50688-2011)" issued by the Ministry of Housing and Urban Rural Development of China, pedestrian crossing facilities should be installed at road intersections. The distance between pedestrian crossing facilities on expressways and main roads should be 300–500 m, and the distance between pedestrian crossing facilities on secondary roads should be 150–300 m.

The spacing data of major road intersections in Luohu District, Shenzhen (Table 15) is based on the table data, which shows that the spacing of all intersections is greater than 150m, in accordance with the national standards.

The main road, Shennan Middle Road, has six intersections and three sections, among which only the distance from the intersection of Bao'an South Road to the intersection of Heping Road meets the national requirement of 300–500 meters. The distance from the intersection of Jianshe Road to the intersection of Dongmen Middle Road and from the intersection of Hongling Middle Road to the intersection of Bao'an South Road has reached over 600 meters, exceeding the national requirement of 300–500 meters.

There are a total of five intersections and three sections on the two secondary roads. Among them, only the distance between the intersection of Bao'an South Road and Guiyuan Road meets the national requirement of 150–300 m. The distance between the intersection of Caiwuwei Third Street and Bao'an South Road, as well as the intersection of Leyuan Road and Wenjin Middle Road, has reached over 300m, exceeding the national requirement of 150–300 m.

Table 15 Distance between Main Road Intersections in Luohu District, Shenzhen

Road category	Road name	Starting point	Termination	Road intersection spacing（km)	Average intersection spacing of roads（Km)
Expressway	Yanhe South Road	Wenjin South Road	Shennan East Road	1.163	0.622
	Yanhe Road Viaduct	Dongmen South Road	Wenjin South Road	0.311	
	Yanhe Road Viaduct	East Ring Expressway Viaduct	Dongmen South Road	0.392	
Main road	Shennan East Road	Jianshe Road	Dongmen Middle Road	0.666	0.543
	Shennan East Road	Bao'an South Road	Heping Road	0.326	
	Shennan East Road	Hongling Middle Road	Bao'an South Road	0.637	
Secondary trunk road	Jiefang Road	Cai Wuwei Third Street	Bao'an South Road	0.488	0.33
	Jiefang Road	Bao'an South Road	Guiyuan Road	0.203	
	Hubei Road	Leyuan Road	Wenjin Middle Road	0.307	
by-pass	Qiaoxing Road	Luofang Road	Jing'er Road	0.254	0.21
	Feipeng Road	Hubei Road	Shennan East Road	0.132	

	Antarctic Road	Chunfeng Road	Shennan East Road	0.236	

4.3 Public Transport Network

4.3.1 Analyze Road Network Density

According to the "Code for Urban Road Traffic Planning and Design" (GB 50220-95) in China, the standard density of the urban road network is 3–4 km/km2 in the central area and 2–2.5 km/km^2 in the urban edge. Luohu District includes 10 streets, all of which belong to the main urban area. The built-up area of Luohu District is 71.32 km^2, and the length of the research bus route is 170.46km. The calculated density of the bus route network in the main urban area of Luohu District is 2.39 km/ km^2. It does not meet the design standards for the density of bus routes in the central urban area, and there are still some areas with bus gaps, which affect the normal travel of local residents. The low density of the urban public transportation network can lead to a decrease in the scope of public transportation services and an increase in passenger walking distance, which is not conducive to passenger travel.

The distribution characteristics of the density of public transportation routes in Luohu District are: The density of public transportation routes in Luohu District is unevenly distributed in space. The density of public transportation routes in the central and southern regions is relatively dense, with a maximum value of 3.5 km/ km^2. The density of public transportation routes in this area meets the requirements of the density standard for urban center areas, making it convenient for residents to travel in this area. The public transportation network in the northeast and northwest regions is relatively sparse, with a maximum value of only 0.6 km/ km^2. The density of the public transportation network in this area has not met the requirements of the density standard of the urban center area, and the travel of residents is not convenient enough.

4.3.2 Analyze the Length of the Road Network

The appropriate length of a bus route depends on the average distance traveled by passengers on that route. If the route is too long, it will reduce the turnover rate of the bus, increase the waiting time for passengers, and increase the probability of vehicle delay, while also increasing the operating cost of the bus route, reducing the transportation efficiency and economic benefits of the bus route. If the route is too short, it will reduce the utilization rate of buses, increase the number of transfers for residents to take public transportation, and, to some extent, increase the pressure on urban transportation.

According to the "Code for Urban Road Traffic Planning and Design (GB50220-95)," the length of bus routes should not exceed the maximum limit: the one-way length of general urban bus routes is 8–12 kilometers, not exceeding 13 kilometers, and the length of the public transportation network in Luohu District is 170457.21 meters.

4.3.3 Analyze the Non-linearity Coefficient of the Road Network

56% of the bus routes in Luohu District meet the design specifications, and the non-linear coefficient values of the routes are higher than the design specifications. This is mainly due to the influence of the urban spatial structure and natural conditions in Luohu District.

From the non-linear coefficient characteristics of each route, the non-linear coefficient of suburban lines is smaller than that of urban lines. Among the 56 bus routes that meet the design specifications and standards, only 18 urban lines account for 32.1%. The suburban lines are relatively straight and have small detours, while the urban lines are influenced by buildings and have more detours, resulting in a relatively high non-linear coefficient. Among them, M485, M140, B909, E13, B621, 333, 337, E13, M103, M482, 62, peak lines 33, 29, M482, etc. are particularly obvious and even affect the travel time of passengers. The route direction should be adjusted appropriately to reduce detours.

4.3.4 Analyze the Road Network Repetition Coefficient

The repetition coefficient of the public transportation network reflects the degree of waste in the capacity of public transportation routes. In the "Code for Urban Road Planning and Design (GB50220-95)," only the definition is given: the repetition coefficient of public transportation lines refers to the ratio of the total length of public transportation lines to the length of the regional road network, without specifying specific regulatory requirements. The coefficient of route repetition is also the ratio of route density to network density, where route density refers to the ratio of the total length of bus operating routes to the land area of cities with bus services, and network density refers to the ratio of the road mileage of routes arranged in the area to the land area of cities with bus services. For a given section, its value is the number of lines passing through that section. According to the Transportation Engineering Manual, it is recommended to have a network repetition coefficient of 1.25–2.5.

The repetition coefficient of Luohu District is about 1.52 (as shown in Table 16), which complies with the provisions of the Traffic Engineering Manual.

Table 16 Repetitive coefficient of bus routes

Road name	Length（km）	Repetition coefficient
Bus routes in Luohu District	170457.21	1.52
Luohu District Road Network	259404.54	

4.3.5 Analyze Average Station Distance

According to the requirements of the Urban Road Traffic Planning and Design Standard (GB-50220-95), the average station distance in the urban area should not exceed 400m, and the average station distance in the suburbs should not exceed 800m.

The average distance between bus stops in Luohu District, Shenzhen, is 168.67m, which is much lower than the standard and meets the standards (Table 17). Among the 361 intervals, only 15 intervals in the above table have a distance greater than 400m, indicating that the infrastructure level in Luohu District is relatively good.

Table 17 Average Bus Station Distance

Starting station	Arrival station	Distance
Tongxin Garden	Changling East Bus Station	862.82
Sanjiu Garden	Sanjiu Road Intersection	555.18
Qinghu Villa	Qingshuihe Logistics Park	476.41
Luofang Village Archway	Anfang Primary School	470.81
Anfang Primary School	Luofang Village Archway	470.81
Luofang Sancha River	Luofang Water Purification Plant	462.41
Wutongshan Bus Station	Tiger Bamboo Scare	454.66
San Tin Village	Lanke Center	451.34
Taojinshan Greenway South Station	Taojinshan Community	425.48
Taojinshan Community	Taojinshan Greenway South Station	425.48
Luofang Water Purification Plant	Luofang South Road	424.03
Cuirong Garden	Xianhu Maple Scenery	417.41
Sungang Railway Station	Tianbei New Village	416.97
Honghu West Road North	Honghu Park 2	414.41

4.3.6 Analyze Station Coverage

According to the requirements of the Urban Road Traffic Planning and Design Standard (GB-50220-95), the service area of public transportation stations, calculated with a radius of 300m, shall not be less than 50% of the urban land area; Calculated with a radius of 500m, it should not be less than 90% (Figure 6):

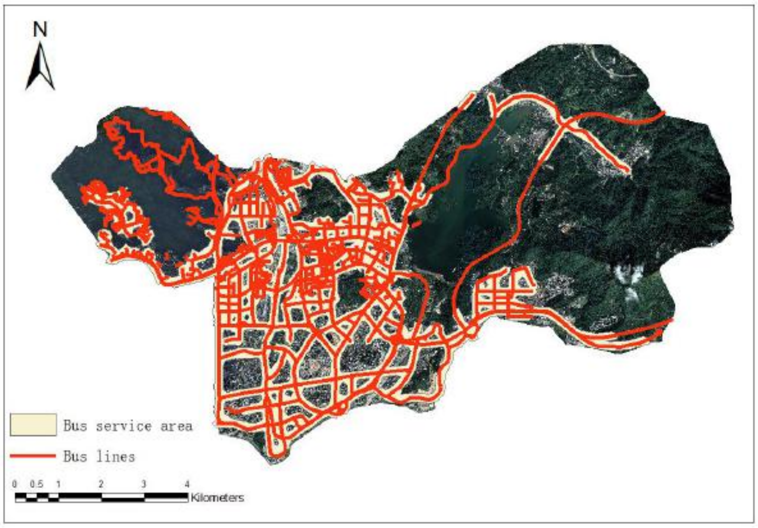

Fig.6 800m Bus Service Area in Luohu District

The data on the coverage rate of bus stops in Luohu District, Shenzhen, shows that the urban bus coverage rate within 500m is only 34% (Table 18), far below the standard value.

Table 18 Bus Station Coverage

Number of bus stops	Bus stop 500m service area (square kilometers)	Built-up Area	Bus stop coverage rate (%)
360	24.83	71.32	34.82

V. CONCLUSION

This article uses GIS to conduct spatial analysis on land use data, road data, and public transportation data in the built-up area of Luohu District, Shenzhen. Combined with national standards, the following conclusions are drawn:

1. Analysis of Land Use in Luohu District

From the perspective of per capita construction land indicators, Luohu District in Shenzhen belongs to a Class IV climate zone, with a per capita urban construction land area ranging from 65.0 to 110.0 square meters and a per capita urban construction land area of 70.1 square meters per person in Luohu District. It meets the scope of this standard. From the perspective of per capita individual construction land, the land for green spaces and squares is 43 square meters per person, which meets the national standard requirements; the road and transportation land is 0.5 square meters per person, which does not meet the requirements; and the residential land is 13 square meters per person, which does not meet the requirements. From the perspective of land structure proportion, residential land accounts for 19%, which does not meet the range of 25.0–40.0% in national standards, while public management and public service land account for 6%, which meets national standards. The proportion of industrial land is 2%, which does not meet national standards. 1% of the land used for roads and transportation facilities does not meet national standards. The proportion of green space and square land is 62%, which does not meet national standards. Overall, the per capita construction land in Luohu District meets the standards, and the ratio of per capita individual construction land to land structure does not meet the standards (Table 19).

Table 19 Analysis of Land Use condition

Index	Types	Present situation	Standard	Evaluate whether it meets the requirements
Per capita construction land	Per capita construction land area	70.1 ㎡/person	[65.0,110.0]㎡/ person	yes
Per capita single construction land	Green space and square land	43 ㎡/ person	≥10.0m2/ person	yes
	Roads and transportation land	0.5 ㎡/ person	≥12.0 m2/ person	no
	Residential land	13 ㎡/ person	≥23.0m2/ person	no
Land use structure ratio	Green space and square land	62%	[10.0%,15.0%]	no
	Roads and transportation land	1%	[10.0%,25.0%]	no
	Residential land	19%	[25.0%,40.0%]	no
	Public management and public service land	6%	[5.0%,8.0%]	yes
	Industrial land	2%	[15%,30%]	no

2. Urban Road Analysis

The maximum longitudinal slope of the main road in Luohu District meets the technical indicators of Chinese highways, and the road is gentle. Due to the population of 1.018 million people in Luohu District in 2022, the total urban road area ratio is 21.87%, which is 6.87% higher than the standard. Therefore, the proportion of road area in Luohu District to the urban construction land area is too high and does not meet the standard. The spacing between the intersections of expressways and branch roads in Luohu District complies with the Design Specification for Urban Road Traffic Facilities (GB 50688-2011), while the main and secondary roads do not comply. Therefore, excessive road area will affect the land occupation of other types of land, and excessive spacing between intersections of main and secondary roads will affect the convenience of transportation. Overall, the roads in Luohu District still need to be adjusted (Table 20).

Table 20 Analysis of Land Use condition

Index	Types	Present situation	Standard	Evaluate whether it meets the requirements
Maximum slope of vertical section	Main road	[0.05%,4.13%]	≦5%	yes
Road area	Four levels of roads	21.87%	[8%,15%]	no
Road intersection spacing	Expressway	622m	≥150m	yes
	Main road	543m	[300m,500m]	no
	secondary trunk road	330m	[150m,300m]	no
	by-pass	210m	≥150m	yes

3. Analysis of Urban Bus Routes and Stops

The density of bus routes in the main urban area of Luohu District is 2.39 km/ km2, which does not meet the design standards for bus route density in the central urban area. Some areas still have bus blank areas, which affects the normal travel of local residents. The average length of the road network is 7.51km, which meets the standard of [8, 13] km. The non-linear coefficient is 1.62, which does not meet the standards of the design specifications. The repetition coefficient of Luohu District is 1.52, which meets the standard. The average distance between bus stops is 168.67m, which meets the standards. The coverage rate of urban public transportation within 500m is only 34%, which meets the standard. Therefore, the overall situation of bus routes in Luohu District is unreasonable, reducing the utilization rate of buses and increasing the number of transfers for residents to travel by bus, which to some extent increases the pressure on urban transportation (Table 21).

Table 21 Analysis of urban bus routes and stops condition

Index	Present situation	Standard	Evaluate whether it meets the requirements
Road network density	2.39 km/km2	[3,4] km/km2	no
Road network length	7.51km	[8,13] km	yes
Non-linear coefficient	1.62	≦1.4	no
Repetition coefficient	1.52	[1.25,2.5]	yes
Average stop spacing	168.67m	≦400m	no
Site coverage	34%	≥90%	no

In summary, based on the evaluation of land use, road system, and public transportation routes in Luohu District, it is recommended to actively implement the "Management Regulations on Supporting the Development of the Real Economy and Promoting the Conservation and Intensive Use of Industrial Land in Shenzhen" in future development, further promote the structural reform of the land supply side, better utilize existing land resources, and promote the conservation and intensive use of industrial land; to build more roads and expand the road area; and properly convert the green area into roads and industrial land.

ACKNOWLEDGEMENTS

The author is grateful for the research grants given to Ruei-Yuan Wang from GDUPT Talents Recruitment (No.2019rc098), Peoples R China under Grant No.702-519208, and Academic Affairs in GDUPT for Goal Problem-Oriented Teaching Innovation and Practice Project Grant No.701-234660.

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