Research Paper

Environmental Assessment of Urban Rail Transit Station Area Based on TOD Mode

A Case Study of Ranjiaba Station in Chongqing

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Abstract

With China's economic development has entered the new normal and the urban development has entered the transformation stage of high-quality development, the TOD mode has become an important starting point to realize the transformation of high-quality urban development.The rail transfer station area is an important area with extremely high urban development intensity, large population and extremely complex transportation.However, due to the construction of rail transit system lags behind land use, the lack of relevant research in China, leading to the current regional development of rail transfer stations is limited.Therefore, based on the geographic information system evaluation tool, taking the Chongqing Ranjiaba transfer station area for example, we construct the built-up environmental evaluation index system under the TOD mode, using the method of visualization and quantification, summarize the environmental characteristics and its weak links.On the basis of the above, this paper puts forward targeted suggestions for the optimization of land use and traffic system which are more suitable for the current TOD development, and provides experience and strategy for the future construction of urban rail transfer station.

Keywords

TOD, rail transfer station, built environmental evaluation, land use, traffic system

1. Introduction

The concept of TOD was first proposed in the 1980s, and was one of the most successful models of urban and transportation sustainable development.In the 1990s, Peter Calthorpe systematically discussed the definition, type, design and key points of TOD, setting a detailed set of detailed and specific guidelines for TOD. Then Cervero and Kockelman put forward the "3D" principle of TOD in 1997: density, diversity, reasonable design, through reasonable design to ensure that the relatively high density of development conditions to provide different groups of people with multi-level choices.In 1998, Cervero added two new items to the original "3D" principle: "distance" and "destination accessibility" principle.In a sum of all, Transit-oriented Development is an urban development and construction model with the concept of bus priority, mixed land use and suitable walking as the core.Today, TOD has been seen as an important way to realize the integration of transportation and land use, promote the intensive and diversification of land use, and form green transportation leading urban development.

The Outline of the National Comprehensive Three-dimensional Transportation Network Plan puts forward new requirements for the development of urban transportation and TOD, and the TOD mode has become a key starting point for leading the high-quality urban development.The rail transfer station area has a number of converging rail transit lines, which is not only a space for dispersing passengers and

transforming transportation modes and routes, but also a place with highly concentrated commercial, office, cultural, residential and other functions, carrying important urban functions and a hub area to promote the development of TOD in big cities.However, due to the complex construction of urban rail transfer stations and the long construction cycle, the development of rail transit lags behind the development of surrounding land, and it is difficult to play the role of TOD mode in promoting the new round of high-quality urban development.

Therefore, taking the Ranjiaba transfer station area of Chongqing as an example, this paper collects the corresponding GIS vector geographic data, POI data, mobile phone signaling data and other data, and through the evaluation tool of GIS system, establishes the corresponding evaluation index system from the two dimensions of land use and traffic system in the track station area, evaluates the coordinated development degree of urban rail transit system and land use under TOD mode, analyzes the weak links in the construction environment of Ranjiaba transfer station area, and taps the development potential. Thus, it can guide the coordinated construction and development of land use and traffic system in the rail transfer station area, and provide practical experience for the planning and construction of the follow-up rail station area.

2. Evaluation system construction

2.1. Scope of study demarcation

The scope of influence on TOD station regional development at home and abroad is generally divided into three categories.One for empirical value, generally in the urban area to choose 500m-1000m, in the suburbs is 2000m-3000m.The second is the empirical analysis, through the case study of the value-added effect of housing prices from the rail transit station of different distances to determine the range of influence.Finally, the theoretical model, and the land price function model is used to calculate the influence range of urban rail transit stations.

For Chongqing, China, the scope determined by the above method is a circular area of rules, not fully consider the mountain city road network structure and walking system, and the actual residents walk 10 minutes walk to reach the area there is a certain gap, and the crowd activity space does not match, need to adjust the service area according to the actual situation. Therefore, this paper uses GIS network analysis tools to determine the area area centered on the track station, with the jagged edge of the urban pedestrian road, that is, the station as the center, walking distance of about 1000m, walking time of about 15-20min to reach the area closely related to the track function as the actual service area.

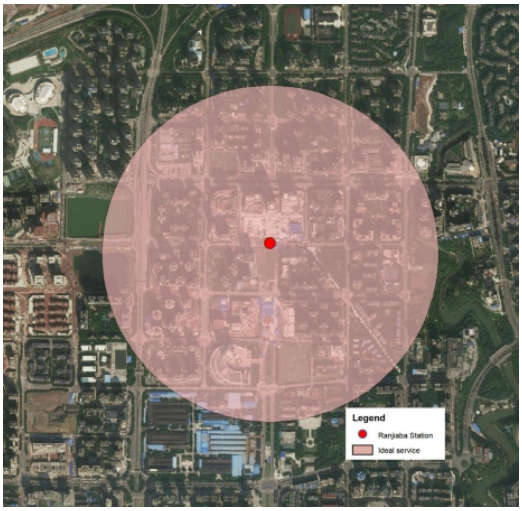


Figure 1. Ideal service. Source: Author Self-Made.

Figure 2. Actual service. Source: Author Self-Made.

2.2. Selection basis of evaluation indicators

This study has three main basis for the selection of evaluation indicators.Firstly, the basic connotation, characteristics and principles of TOD mode are taken; secondly, the evaluation index adopted by relevant domestic and abroad as reference; and finally, the spatial characteristics of the main urban area of Chongqing are taken as the realistic basis of evaluation index selection.At present, scholars' selection of evaluation indicators focuses on the level of macro-urban system, mostly covering economy, society, transportation, space and other aspects, and placing more emphasis on comprehensiveness.This study focuses on the micro-planning and construction level, so when drawing on the research results of relevant scholars, more attention is paid to the selection of land use and traffic system for the measurement and applicability of relevant indicators, so as to provide a practical basis for the selection of indicators.

2.3. Construction of the evaluation index system

On the basis of clarifying the previous problems, combined with the "5D" principle of TOD model, we should establish a multi-level micro-evaluation index system of track stations reflecting the comprehensive development of urban rail transit and land use, from emphasizing the development of technical measures to emphasizing performance. The evaluation system is expanded according to the hierarchy, the target layer is the construction environment level of the TOD station in the urban rail interchange area, the evaluation dimension is expanded from two aspects, and contains three evaluation criteria layers, the specific indicators further extract the leading factors from the evaluation criteria, including floor area ratio, land mixing degree, road network density and other 10 indicators, respectively, used to quantify the TOD mode station land development utilization and rail transit development level.

Table 1. Environmental assessment system of urban rail transfer station area . Source: Author Self-Made.

Evaluation objectives	First criteria	Second criteria	Indicator layer
The level of built-up environment in the urban rail transfer station area under TOD mode	Land use	Land layout structure	L1 Floor area ratio
			L2 Main land supply ratio
			L3 Land mixing degree
		Population concentration	L4 Unit area population
		Street vitality level	L5 Commercial facility ratio
	Traffic system	Road construction level	T1 Road network density
		Walking space quality	T2 Connectivity index
			T3 Bypass Index
		Public transport links	T4 Total bus services
			T5 Track coverage ratio

Table 2. Analysis of indicators in the index layer. Source: Author Self-Made.

Indicator	Indicator paraphrase	Formula
L1 Floor area ratio	Clarify the driving degree of the station to the land use and development intensity.	$L1 = \frac{S_A}{S_r}$ S_A: Total floor area; S_r: Total land area

L2 Main land supply ratio	Reflect the employment driving capacity of the station area and the overall level of regional economic development.	$L2 = \frac{\sum_{i=1}^{m} H_i S_i + \sum_{i=1}^{n} H_i S_i + \sum_{i=1}^{o} H_i S_i}{S_r}$ H_i: Building height; S_i: Building coverage; S_r: Service area; m: commercial buildings; n: office buildings; o: residential buildings
L3 Land mixing degree	Reflects land use diversity in track station areas.	$L3 = \frac{\sum_{j=1}^{J} p_j \ln p_j}{\ln J}$ p_j: Proportion of the building area to the floor area ratio of each type of land; J:Total number of land types
L4 Unit area population	Reflects the current overall population agglomeration level in the station area.	$L4 = \frac{N_h + N_w}{S_r}$ N_h: Number of inhabitants; N_w: Number of people working; S_r: service area
L5 Commercial facility ratio	Reflects the diversity of street function and population activity in the station area.	$L5 = \frac{\sum_{i=1}^{m} f_i S_i}{S_r}$ f_i: Building height; S_i: Building coverage; m: commercial buildings; S_r: service area;
T1 Road network density	Evaluation common indicators reflect the overall level of road construction in the station area.	$T1 = \frac{R_l}{S_r}$ R_l: Total length of roads in the service area; S_r: service area
T2 Connectivity index	Characterization of the closeness of regional street network connections is an important indicator of walking friendliness.	$T2 = \frac{N_s}{N_j}$ N_s: Number of sections between intersections; N_j: Number of intersections and end-of-road
T3 The bypass index	Reflects the accessibility of walking paths within the track station area.	$T3 = \frac{i_q r}{\sum_1^i l_i}$ i_q: Actual number of walking paths, the general value is 8; r:Service area radius; l_i: Every actual walking path length
T4 Total bus services	Reflects the convenience of pedestrian bus transfer and the supply level of conventional bus stations and lines.	$T4 = \frac{(N_{b1} + N_{b2})}{\pi L_b^2}$ N_{b1}、N_{b2}: Number of bus stops and lines in adjacent areas; L_b: The optimal distance between the track entrance and exit from the bus station, takes a value of 200m
T5 Track coverage ratio	Reflects the tight connection between station areas and other regional track stations.	$T5 = \frac{N_t}{N_Q}$ N_t: Number of stations reached within 30min of the track station N_Q: Total number of rail stations opened in Chongqing

2.4. Selection of evaluation method

In order to avoid calculating the index weights that are too subjective, this study will combine the information entropy method, which is widely used in social economy and other research fields, with the expert scoring method, and determine the index weights comprehensively.The evaluation index system adopted in this paper is mainly based on the basic principles of TOD mode, and the indicators are set as positive, that is, the higher the index value represents the better the reality reflected by the indicator.The specific calculation steps are as follows.

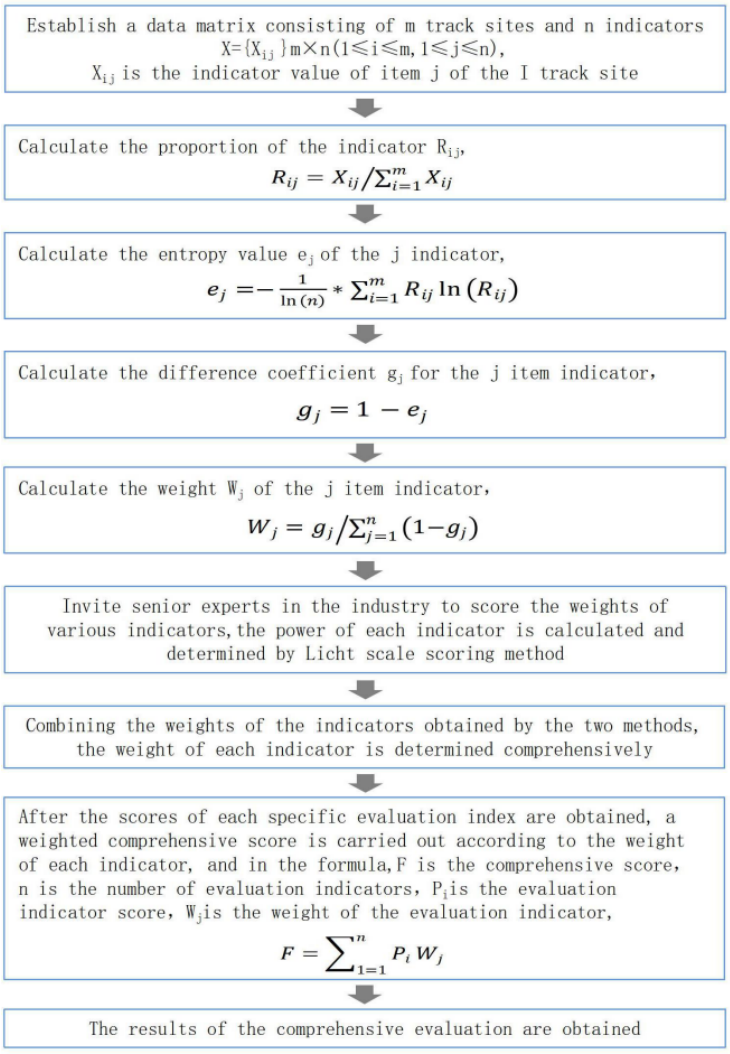


Figure 3. Overall evaluation calculation flow chart. Source: Author Self-Made.

3. Analysis of built-up environment in the area of Ranjiaba transfer station

Ranjiaba Station is a three-line transfer station of Chongqing rail transit Loop Line, Line 5 and Line 6, located in Yubei District, Chongqing, with a total of eight entrances and exits.Ranjiaba transfer station area is in the process of development and construction, with dense residential land, more supporting facilities, relatively perfect road facilities, and a strong agglomeration capacity for the surrounding areas.However, due to the rail transit construction of the station lags behind land use development, the lack of connection with the existing land development situation, poor coordination, the overall land development level of the station area is relatively general, the land development construction is relatively chaotic and disorderly, and the effective comprehensive development under TOD mode has not been formed.

For Ranjiaba transfer station area, we mainly use the current basic data: including Urban Statistics Web data, GIS satellite map and vector data, Baidu map POI data, station system web data, etc. at the same time, GIS system tools are used to comprehensively analyze the environmental level of Ranjiaba Station.Combined with the survey, starting from the needs of cultural activities, commercial and entertainment activities, walking experience, transportation, living and other on, the main problems in the Rangjiaba transfer station area are analyzed as follows.

Table 3. Environmental evaluation results of Ranjiaba Station. Source: Author Self-Made.

L1	L2	L3	L4	L5	T1	T2	T3	T4	T5	Land Use	Traffic system	Total score
29.3	32.9	47.1	57.8	48.3	67.0	100	23.9	95.8	77.0	42.3	59.6	70.9

3.1. Land use issues

(1) Land-use layout structure

The overall land development level of Ranjiaba transfer station area is not high, and the situation of land use function type and structure is poor. The land mixing degree of each type of land is general, and the driving role of rail transit on land use is not obvious.The types of land in the area are mainly residential and administrative office, and then there are more administrative office land and the right amount of commercial land, and a small number of park space and scientific research and education land are sporadically distributed in the area, with a total of 7 different types of land.Residential land in the area is mainly densely distributed in the north and scattered in the south; administrative office land is mainly distributed symmetrically along the north-south Shuanglong Avenue, close to the station with appropriate commercial land. In addition, only some educational and scientific research, medical and health land are scattered, generally the building density is not high.In addition, due to the low proportion of land used for public supporting facilities in the region and the land use types are not diversified enough, there is a certain gap with the rail transfer station area under TOD mode.

(2) Population agglomeration degree

According to the mobile signaling data, the total population and employment in Ranjiaba Station is large, but the main land supply type is not high. The residential population is mainly gathered in the residential areas on the east and west sides, the jobs are mainly distributed in the commercial districts and office buildings, and there is still a certain space for expansion.The main reason is that the development facilities around the station area is not perfect, and there are a number of industrial buildings.From the perspective of spatial distribution, population and post space distribution, densely populated and widely around station distribution, jobs are mainly distributed in a large number of concentrated commercial office and widely distributed public building area, such as China Huarong Modern Square, Red Star Macalline, Longhu Home Huehui, Radio and Television Building, Yangtze river Business Center, etc. another certain amount of jobs scattered in education construction and medical and health buildings.However, the core areas of Ranjiaba Station are mostly large commercial squares, and the business form systems of different levels are incomplete. Most jobs are located in a number of agglomeration points, which do not reach the distribution level of concentrated core areas and clusters.

(3) Street vitality level

In contrast, the total level of street vitality points in Ranjiaba Station is general and evenly distributed, mainly concentrated with the northern contiguous residential areas and the main commercial land in the plot, and the rest are scattered in the plot.Because Ranjiaba Station service area is mostly residential land and mainly distributed in the north of the plot, there are more continuous underlying commercial, development scale is more suitable, and commercial land and mainly concentrated near the station entrance and exit area, so the point of interest is mainly distributed in these areas, Neighborhood openness, street comfort and public vitality are all good, street activity is high.However, a large number of concentrated residential land and administrative office land is usually only a small number of

underlying business, and mainly distributed in the south of the plot, small and medium-sized commercial facilities are insufficient, the overall street activity is low.

3.2 Traffic system problems

(1) Overall level of road construction

On the whole, Ranjiaba transfer station area adopts the form of small block dense road network, the overall road network density is high, and each grade is clear and evenly distributed in the plot. From the data, it is relatively in a position of advantage, laying an overall foundation for the subsequent road optimization and adjustment.However, due to the general pedestrian road connectivity in the connection area at the entrance and exit of the station, and there are many walking detours and blocks in the adjacent plots, the connectivity index is relatively low, and there is a large room for improvement in the construction of walking contact road facilities at the entrance and exit of the station.

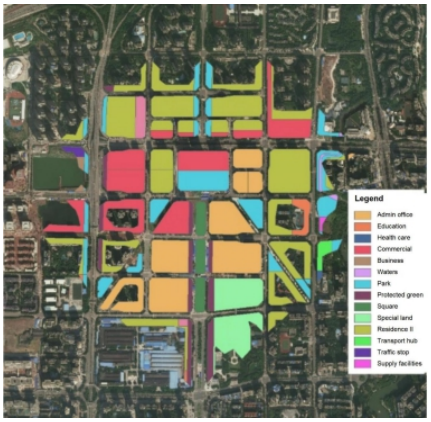
(2) Walking Space Quality

From the perspective of walking path connection, because the Ranjiaba Station is located after unified planning and construction, the surrounding blocks adopt the form of small block dense road network. In addition to the road construction in a few areas, the walking traffic in the area is good,the station has good walking connection with the surrounding area, and the area bypass degree is relatively low.However, due to the barrier of Yusong Road, the main road on the west side, there are more corresponding overpasses and tunnels, and the walking connectivity is poor.In terms of walking traffic environment, on the one hand, the space scale of some squares is too large, and the walking environment design still needs to be improved; on the other hand, walking through the west trunk road and northern business district should rely on overpass and tunnel across the main road, or large scale intersection with large traffic flow, the safety of walking is poor.

(3) Degree of public transport contact

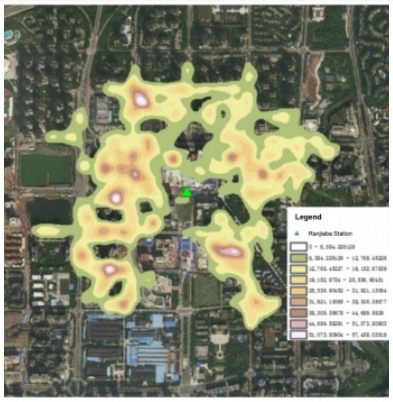
For the transfer between rail stations, because Ranjiaba Station is located in the center of the rail transit network, rail transit Loop Line, Line 5 and Line 6 meet here, half an hour commute covering 81 stations, accounting for more than 50% of the total number of opened stations, commuting coverage is wider, rail transit conversion capacity is strong. For the interchange between the rail station and the bus station, the transfer distance between the outbound entrances and bus stations of Ranjiaba Station is generally greater than 300. The connection relationship between the rail station and the regular bus is general, the total number of bus lines is only 17, and the coverage area is not balanced, the emphasis is on the main traffic road in the region Yusong Road and Xinnan Road, the overall bus line service capacity is low.

Table 4. Environmental visual analysis of Ranjiaba Station area. Source: Author Self-Made.



Distribution of all kinds of land

Distribution of architectural morphology



Overall population distribution

Overall jobs distribution

Distribution of POI

Distribution of bus station and route

Walk path & node

4. Countermeasures and suggestions

4.1 Adjust the conversion of rail transit and regular public transport modes

(1) Increases multi-directional departure points along the secondary trunk roads and branches

Adjust the layout of bus stations, increase the bus lines of the secondary roads and some branches in the area, and set up the main bus stations around the entrances and exits of the rail stations, so as to reduce the transfer distance between the stations.In order to improve the transfer efficiency of rail transit and conventional buses, and reduce the walking behavior of cross roads to buses, the shuttle bus lines to all directions along the secondary trunk road and branch road of the rail transfer station, and a number of sub-line designated stop bus stations are added.

(2) Adjust the operation strategy of rail transit and ground bus during peak hours in due course

The frequency of rail transit and ground bus stops can be increased in due course, and operation speed and station cover rate should be improved, provide a comfortable waiting environment and generous number of seats, improve public transport sharing rate, it is beneficial to cope with the large number of traffic during rush hours such as commutes, weekends and holidays, better service station areas and other areas of traffic, reduce car travel, improve air quality.The establishment of the green channel during the rush hour of rail transit, and make reservations in advance online using mobile phones to reduce the waiting time for security check, which is conducive to epidemic prevention and control and improve traffic efficiency to a certain extent.

4.2 Establish and connect a multi-level territorial public space

(1) Integrates regional characteristic elements into the construction and transformation of public service

Rich and varied commercial facilities along the street and well-laid public service facilities are important factors that trigger residents' walking activities.

Because the station is located in the urban rail transfer station area, large traffic, regional construction is not yet mature, you can integrate the cultural elements of the Ba-shu mountain into the original public service facilities, such as community greening, street squares, park green space, with the help of landscape elements, rail transit elements, lighting elements, etc. create a crowd activity place and atmosphere.In addition, more open-air publicity, exhibition and activities will be open to introduce traditional Bayu-architectural elements into public buildings and commercial service facilities.

(2) Shapes a continuous node space based on the main functions

Ranjiaba transfer station is distributed in contiguous residential areas, administrative office areas and commercial districts, streets crisscross, relatively low dense buildings, with diversified public space.In order to trigger the walking behavior of station users, effective correlation space should be established between the complementary functions of blocks, first establish associations between commercial and commercial functions, and then establish indirect associations between commercial and residence.Clear walking roads, configure small light activities and lighting facilities, you can make full use of the idle space.Due to the limited urban public space resources, we should make full use of the characteristics of rail transit itself, and combine the unified planning and overall design of the surrounding areas with architecture, municipal administration and landscape, so as to improve the comprehensive utilization value of land.

4.3 Optimize the experience of walking environment

(1) Jointly develop the station with the building

First of all, combined with the layout of the surrounding block functions, reasonable functional connectivity is conducted, and secondly, the residents around the station are carefully analyzed by the market demand, the location of the rail transit station, the surrounding environment, users' consumption intention and living habits, to build a four-dimensional spatial function mode.It is suggested to combine subway entrances and exits with large public buildings to jointly develop underground commercial space, and set up air corridors in sections or intersections with large traffic flow.

(2) Increases the type and density of the underlying business along the street as much as possible

Professor Jan Gehl suggests that pedestrian-friendly streets have 13 underlying business per 100 metre, and commercial facilities along the street are important to improve the walking experience.Therefore, for the residential areas around the station, we should not only try to open up the walking road connection of the residential areas as far as possible, but also supplement the continuous street bottom business, to solve the problem of convenience of life closely related to the lives of residents. Bbecause of the special mountain landform in Chongqing , leading to the tension of urban space land, and transfer to the diversification of traffic mode, traffic functions, commercial functions, mixed functions and other public facilities and urban space in the vertical direction are proved. The site is combined with terrain and building space to make use of the composite, thus forming a multi-layered three-dimensional development model with mountain characteristics. At the same time, according to the actual situation, we should appropriately expand walking roads, extensive greening, increase lighting facilities, and form a network connecting parks, squares, green space and urban building space.

(3) Improve the safety and comfort of trunk roads

Regional overpass and underground passage is a good measure to avoid traffic flow and people conflict, at the same time, consider the combination of the station area function, series business, office, residential functions, encourage the adoption of government and enterprises to jointly build public facilities strategy, so as to form a convenient functional link to reduce the financial pressure of the development process.For example, the planning and design can be combined with commercial buildings, the government encourages developers to build more public facilities with floor area ratio compensation, so as to create three-dimensional walking space with diversity of ground and air in the transfer station area.

5. Conclusion

The concept of TOD was first proposed in the 1980s, as one of the most successful models of urban and transportation sustainable development, TOD is an important way to realize the integration of transportation and land use, promote the intensification and diversification of land use, and form green transportation leading urban development.As an important hub with extremely high development intensity in the urban rail transit system, large population agglomeration and extremely complex transportation, the rail transfer station area can not only significantly improve the overall operation efficiency of the rail transit, but also effectively promote the comprehensive development and utilization of regional resources at the station, and plays a pivotal position.

Under the background of the transformation of high-quality urban development in China, in view of the transportation system and land use imbalance in the mountain city rail transfer station area, this paper puts forward the environmental evaluation index system based on the TOD model, evaluates the status quo of the mountain city rail transfer station area through GIS tool, so as to clarify the status quo of the station area, the corresponding land use and transportation system optimization proposal is of better reference to the subsequent planning and construction of other rail station areas in Chongqing, especially in the urban transfer station area.

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